PART 3
KEY MESSAGES: LESSONS TO BE LEARNED FOR AGRICULTURAL PRODUCTION NETWORKS AND FOOD VALUE CHAINS

Hiroyuki Nakata concentrates on the effects of natural disasters on company behaviour in an oligopolistic market by closely observing the changes in price and quantity. He transfers his experience from the hard disk drive industry and flood events to agricultural production networks. Contrary to the more common view that firms directly affected by natural disasters are victims, he presents cases showing that companies can profit from disasters by acting collusively. He generates the hypothesis that certain actors in the value chain can take advantage of natural disasters while others, namely the producers, carry the burden.

Willem Thorbecke speaks about trading networks in the manufacturing sector in East Asia. These are associated with technology transfer, mushrooming productivity growth, and tumbling prices for final goods. Similar value chains have yet to emerge in Asia in the agricultural sector. To promote agriculture, Asian countries should harmonise bio-security standards; rethink agricultural self-sufficiency; eschew protectionism; focus on comparative advantages; and foster cooperation between research agencies, the government, and commercial enterprises.

Venkatachalam Anbumozhi discusses the effects of natural disasters on water management and regional food value chains. For Asia, biophysical crop model results show yield reductions under climate-changed scenarios compared to those with no climate change. By 2050, the expected reduction is in the range of 14%–20% for irrigated paddies; irrigated wheat, 32%–44%; irrigated corn, 2%–5%; and irrigated soybean, 9–18%. Disaster damage comes on top of this. ASEAN countries experienced nearly 40% of the global total of natural disasters in 1990–2011. The optimisation of regional food value chains is critical for the regional food supply.

Kim Yeon Tae and Malinee Phonsuwan argue that the agricultural sector continually adapts to climate change through changes in crop rotation, planting times, genetic selection, fertiliser management, pest management, water management, and shifts in areas of crop production. The agriculture sector – in particular, industrial agriculture – is dependent on effective information for warning and preventing losses in the food supply chain. In Korea, industrial agriculture uses advanced methods of information and communications technologies to match cropping practices to climatic trends, use inputs sustainably, and cope with productivity threats

Chapter 7

The Different Vulnerabilities of Industrial and Agricultural Products Against Rare Disasters: Lessons to be Learned from the Hard Disk Drive Industry

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CHAPTER 7

THE DIFFERENT VULNERABILITIES OF INDUSTRIAL AND AGRICULTURAL PRODUCTS AGAINST RARE DISASTERS: LESSONS TO BE LEARNED FROM THE HARD DISK DRIVE INDUSTRY

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Introduction

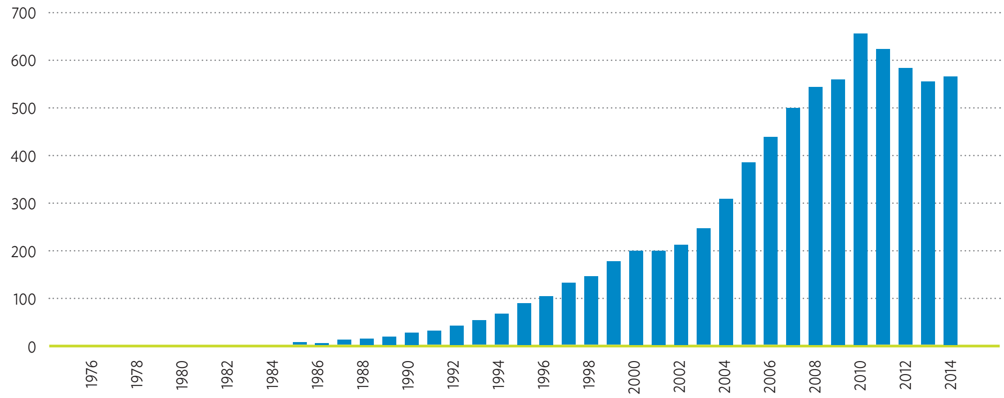
Our paper first reviews the hard disk drive (HDD) industry and the 2011 floods in Thailand. It then introduces a static Cournot oligopoly model and extends it to a dynamic one by following Radner (1980). Other works on cartels include Green and Porter (1984) and, more recently, a review of literature by Levenstein and Suslow (2001). The key question is the condition with which a cartel may be sustained, and the key prediction of Radner (1980) is that the difficulty or ease of sustaining a cartel depends on the number of players when the industry-level demand is a function of the number of players but is independent of the number of firms when the industry-level demand is also independent of the number of firms. The observations about the price and quantity in the HDD industry before and after the 2011 Thailand floods are consistent with the case in which a cartel was formed after the floods. On the other hand, a shift in demand alone cannot explain the behaviour of price and quantity in the industry, although a shift in demand may have happened simultaneously with the formation of a cartel.

Although this paper does not study directly if there was indeed a formation of a cartel in the HDD industry or a shift in demand, it discusses how the issues should be investigated empirically. Based on the analysis on the HDD industry, we discuss the implications for agriculture. One key observation is that the corporate sector, especially the vertically integrated multinational agriculture business, may resemble the HDD manufacturers. Also, the asymmetry between small producers and large corporate middlemen may well cause distortions in the allocation of the costs of risk prevention and/or losses or damage from natural disasters. Based on such observations, we provide some policy recommendations. The rest of the paper proceeds as follows. Section 2 describes the HDD industry and the 2011 Thailand floods, followed by Section 3, which analyses the behaviour of the HDD manufacturers based on the theoretical predictions of Radner (1980). Section 4 discusses the implications of the analysis on the HDD industry, mainly focusing on the incentives to invest in risk prevention, and the implications for agriculture. Section 5 concludes.

The HDD Industry and the 2011 Thailand Floods

This section reports some basic facts about the HDD industry. Figure 1 illustrates annual global shipments of HDDs from 1976 to 2014. With the exception of the dip around 2001 – happening at the time of the collapse of the information technology bubble – HDD shipments kept increasing exponentially until 2010 before the recent decline. Figure 2, on the other hand, reports quarterly global shipments of HDDs from the fourth quarter of 2010 until the fourth quarter of 2014, where we can see a sharp drop in the fourth quarter of 2011, reflecting the disruption of production in Thailand due to the floods. Western Digital's production facility was greatly affected by the floods, halting production. See, for instance, Fuller (2011). Also, for more general discussion about the impacts of the 2011 Thailand floods, see Ministry of Economy, Trade and Industry (2012) and the World Bank (2012).

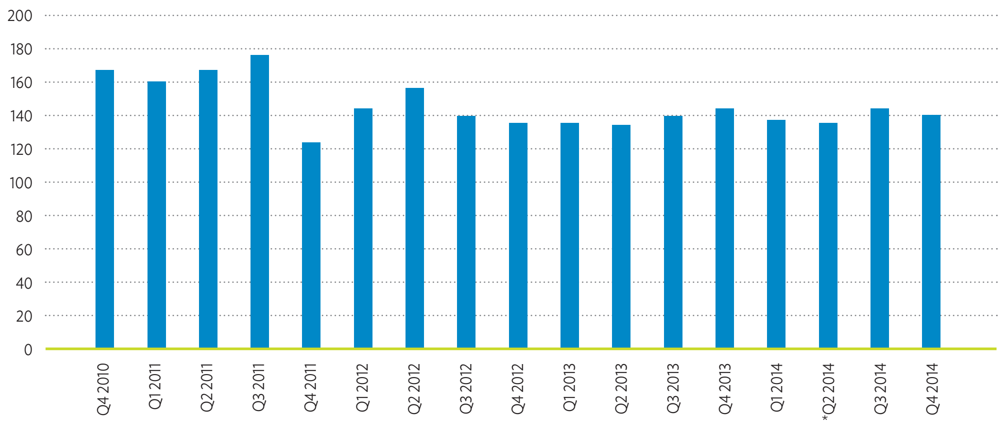
Figure 1: Annual Global Shipments of Hard Disk Drives, in million pieces



Source: TrendFocus, 2015.

The shipments, however, recovered quickly and the level has been stable since then, albeit at a lower level than before the 2011 floods.

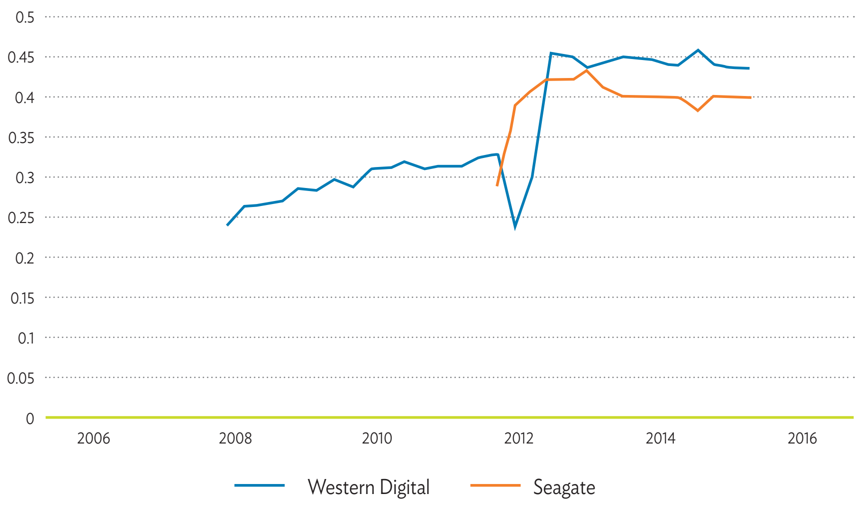
Figure 2: **Quarterly Global Shipments of Hard Disk Drives, in millions**



Source: TrendFocus, 2015.

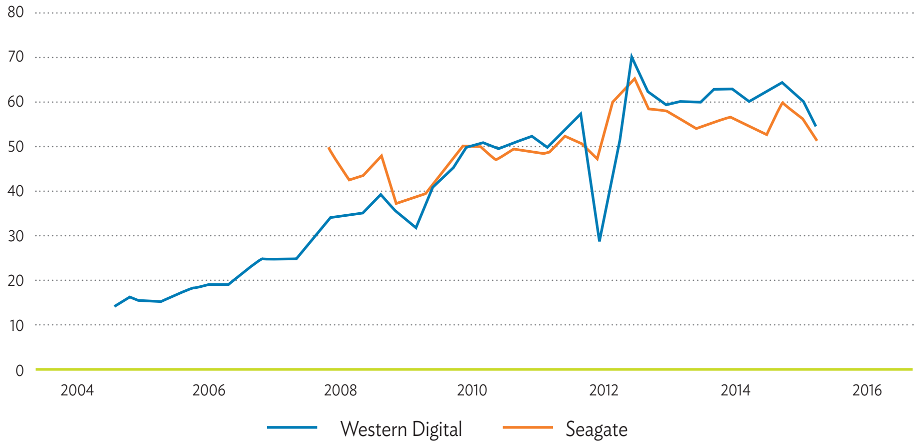
The HDD industry has been through a continuous consolidation process in the past 25 years. Currently, only three players remain in the industry: Western Digital, Seagate, and Toshiba, although the former two are dominant (Figure 3). Seagate purchased Maxtor in May 2006, Toshiba bought Fujitsu's HDD business in October 2009, Seagate acquired Samsung's HDD business in December 2011, and Western Digital obtained Hitachi's HDD business in March 2012, decreasing the number of players from seven to three in 10 years.

Figure 3: **Market Shares of Hard Disk Drives**



Sources: Financial statements of Seagate and Western Digital, 2016.

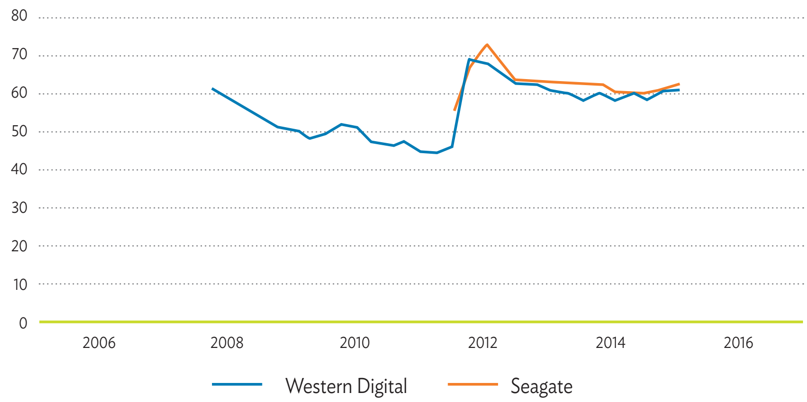
Figure 4: Shipments of Hard Disk Drives, in millions



Sources: Financial statements of Seagate and Western Digital, 2016.

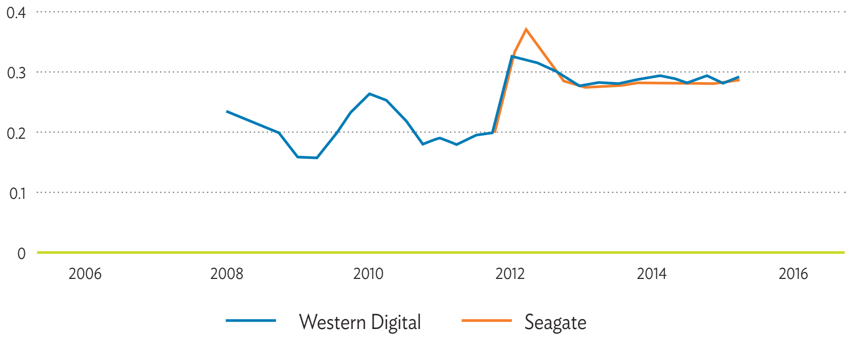
By comparing Figure 3 and Figure 4, we can see that the market shares of Western Digital and Seagate both rose after their acquisitions of the HDD business of Hitachi (Western Digital) and that of Samsung (Seagate) more than the general increase in their shipments. Figure 5 exhibits the average HDD selling price of Western Digital and Seagate. Before the 2011 Thailand floods (fourth quarter of 2011), the average HDD selling price had been in steady decline, at least for Western Digital, but shot up at around the time of the floods, both for Western Digital and Seagate. What is striking is that the average selling price was staying at a higher level than the pre-flood level and was fairly stable. A similar pattern emerged for their gross margins (Figure 6).

Figure 5: Average Selling Prices of Hard Disk Drives (US$)



Sources: Financial statements of Seagate and Western Digital, 2016.

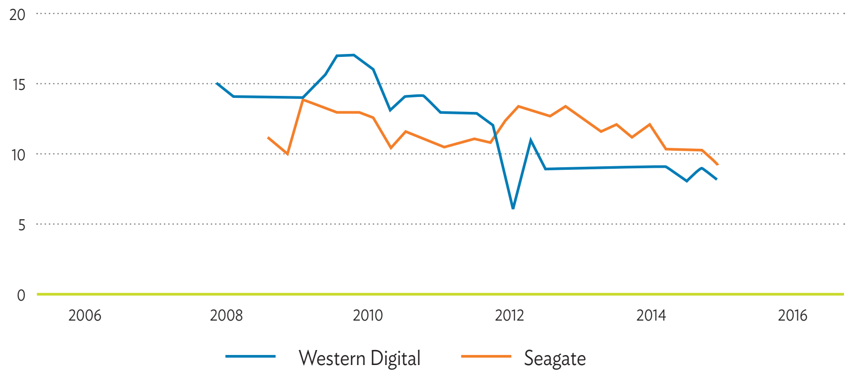
Figure 6: Gross Margins



Sources: Financial statements of Seagate and Western Digital, 2016.

To summarise, the HDD shipments fell slightly and the price (and the gross margins) went up substantially after the 2011 Thailand floods. Figure 7 illustrates the inventory turns of the two major players. Western Digital's inventory turns dropped sharply in the first quarter of 2012, probably reflecting the temporary closure of its production facilities in Thailand, although it had been gradually declining before the 2011 floods, and has been at a low level since the third quarter of 2012.

Figure 7: Inventory Turns of Hard Disk Drives, by Manufacturer



Sources: Financial statements of Seagate and Western Digital, 2016.

In contrast, Seagate's inventory turns increased substantially in the first quarter of 2012, but has been slowly declining since then and is converging to the inventory turns of Western Digital.

Analysis

In what follows, we first present a standard Cournot oligopoly model, and then extend it to a dynamic one with a finite horizon by following Radner (1980). Then we use the theoretical framework to analyse the case of the HDD industry to evaluate the effects of the 2011 Thailand floods.

Static Model

Consider an industry in which there are n firms (or players) indexed by $i = 1, 2, \dots, n$ and there is little or no product differentiation. Each firm i can choose its production level Q^i directly but not the price of its product, i.e. the industry is in a Cournot oligopoly, and the firms are facing an inverse demand function

$$P = \alpha - \beta Q,$$

where P denotes the price and is Q the aggregate quantity of the product produced, i.e. $Q = \sum_{i=1}^{n} Q^i$. By letting $Q^{-i} := \sum_{j \neq i} Q^j$, we can express $Q = Q^i + Q^{-i}$, i.e. the aggregate production is decomposed into firm i's production and that of all other firms. The cost function of the firms is assumed to be identical and that of constant returns to scale, $(Q^i) = cQ^i$, where the parameter c is both the marginal and average cost. We assume $\alpha > c$.

Each firm solves the following optimisation problem:

$$\max_{Q^i} P\left(Q^i + Q^{-i}\right) \cdot Q^i - cQ^i \text{ subject to } Q^{-i} \text{given.}$$

It is straightforward to show that the solution to this problem $Q^i\left(Q^{-i}\right)$ is

$$Q^i\left(Q^{-i}\right) = \frac{\alpha - c}{2\beta} - \frac{Q^{-i}}{2} \text{ if this is non-negative and zero otherwise.}$$

Thus, in the symmetric Cournot-Nash equilibrium, $Q_c^{-i} = (n-1)Q_c^i$ holds, where subscript c indicates that the quantity is in a Cournot-Nash equilibrium. It follows that each firm's equilibrium quantity is $Q_c^* = \frac{\alpha - c}{(n+1)\beta}$, and the equilibrium price is $P_c = \frac{\alpha + nc}{n+1}$. Thus, the equilibrium aggregate quantity is $Q_c = \frac{n}{n+1} \cdot \frac{\alpha - c}{\beta}$, which converges to $\frac{\alpha - c}{\beta}$ as the number of firms goes to infinity, i.e. the equilibrium quantity in a competitive equilibrium, in which the price equals the marginal cost.

Now, consider the case in which all firms in the industry form a cartel so that they behave as though they are in a monopoly. This case can be described above by setting $n = 1$ for the aggregate quantity and for the price, i.e. $Q_m = \frac{\alpha - c}{2\beta}$ for the aggregate quantity and $P_m = \frac{\alpha + c}{2}$, where m indicates monopoly. Thus, the aggregate quantity Q_m is smaller than Q_c, i.e. $Q_m < Q_c$ in the symmetric Cournot-Nash equilibrium and the equilibrium price P_m is higher than P_c, i.e. $P_m > P_c$ when $n \geq 2$. Each firm will produce $Q_m^* = \frac{\alpha - c}{2n\beta}$, which is smaller than Q_c^*, i.e. $Q_m^* < Q_c^*$ for all i when $n \geq 2$.

Finite-Horizon Dynamic Case

We now consider a dynamic case with a finite horizon by following Radner (1980). Let T denote the number of periods, and we assume that the firm's payoff is the average of the T one-period profits. Each firm plays a sequential T-period game in which the one-period game is repeated T times.

As noted by Radner (1980), in every perfect Cournot-Nash equilibrium of the T-period game, each firm produces Q_c^* in each period. Radner (1980) then considers the following strategy: firm i produces Q_m^* $(< Q_c^*)$ in each period as long as all other firms have been doing the same; thereafter firm i produces Q_c^* in each period. This strategy is denoted by C_T, which is defined formally below. First define D_i as follows:

$$D^i = \begin{cases} \infty & \text{if } Q_t^j \text{ for all } t \text{ and all } j \neq \text{i}, \\ \min\{t: Q_t^j = Q_m^* \text{ for some } j \neq i\}, & \text{otherwise.} \end{cases}$$

The strategy C_T is defined by

$$Q_t^i = \begin{cases} Q_m^* \text{ if } t \leq D^i, \\ Q_c^* \text{ if } t > D^i. \end{cases}$$

More generically, for any integer k between 0 and T, define the strategy C_k as follows:

$$Q_t^i = \begin{cases} Q_m^* \text{ if } t \leq \min(D^i, k), \\ Q_c^* \text{ if } t > min(D^i, k). \end{cases}$$

Radner (1980) further considers a more general class of strategies below, which he called trigger strategies of order k. Let Q^D some (defection) production level. If $D^i \geq k$, then

$$Q_t^i = \begin{cases} Q_m^* \text{ if } t \leq k, \\ Q^D \text{ if } t = k + 1, \\ Q_c^* \text{ if } t \geq k + 2. \end{cases}$$

If $D^i \leq k$, then

$$Q_t^i = \begin{cases} Q_m^* \text{ if } t \leq D^i, \\ Q_c^* \text{ if } t > D^i. \end{cases}$$

With these trigger strategies, Radner (1980) shows the following:

Proposition 1 (Radner, 1980): Suppose all firms other than firm i use the same trigger strategy of order $k > 0$ with some defection production level $Q^D > Q_m^*$. Then, firm i's best response is a trigger strategy of order $(k-1)$, with defection production level equal to

$$\tilde{Q} := \frac{(\alpha - c)(n+1)}{4n\beta}.$$

An important implication of this result is that the advantage to any one firm of defecting from the cartel one period before the end of the game approaches zero as the number of periods $T \longrightarrow \infty$ provided that all other firms use trigger strategy of order T. The result can be verified by comparing the average profit per firm when using a trigger strategy of order $(T-1)$ and the cartel profit per firm.

Radner (1980) then introduces an equilibrium concept that is looser than the standard Nash equilibrium: epsilon-equilibrium, which is defined as follows:

Definition (Epsilon-equilibrium; Radner, 1980): For any positive number ε, an ε-equilibrium is an n-tuple of strategies, one for each firm, such that each firm's average profit is within ε of the maximum average profit it could obtain against the other firms' strategies.

Radner (1980) applies this definition to the dynamic case by extending the concept of perfect Cournot-Nash equilibrium, which is called a perfect ε-equilibrium. One central ε-equilibrium of interest is the one in which each firm produces its cartel output level for exactly k periods, i.e. combination (C_k) of trigger strategies. Furthermore, two cases are considered: (a) the fixed-demand case, and (b) the replication case. In the former case, the aggregate demand is independent of the number of firms, while it is a function of the number of firms in the latter case – more specifically, $Q = \left(\frac{\alpha - P}{\beta_1}\right) \cdot n$. The following two results are shown by Radner (1980). First, for the fixed-demand case:

Proposition 2 (Radner, 1980; Fixed-demand case): Consider the fixed-demand case. For every $\varepsilon > 0$ and $T \geq 1$ there is a number $B(\varepsilon, T)$ such that for every $n > 1$ and every ε-equilibrium, the following are all bounded by $B(\varepsilon, T)$:

$$\left|Q_t^i - Q_c^*\right|,$$

$$\left|\sum_{i=1}^{n} Q_t^i - nQ_c^*\right|,$$

$$\left|\left(\alpha - c - \beta Q_t^{-i}\right) \cdot Q_t^i - \beta \cdot \left(Q_t^i\right)^2 - \frac{1}{\beta} \cdot \left(\frac{\alpha - c}{n+1}\right)^2\right|,$$

for $i = 1, 2, \dots, n$. $t = 1, 2, \dots, T$. In addition, for every T,

$$\lim_{\varepsilon \to 0} B(\varepsilon, T) = 0.$$

The first line states that the deviation of firm-level production from the Cournot-Nash equilibrium firm production level is bounded by $B(\varepsilon, T)$. Similarly, the second line is regarding the industry-wide production level and the third line is on the firm's profit. Next, for the replication case:

Proposition 3 (Radner, 1980; Replication case): Consider the replication case. For every $\varepsilon > 0, T \geq 1$ and $n > 2$, there is a number $B(\varepsilon, T, n)$ such that for every $n > 1$ and every ε-equilibrium, the following are all bounded by $B(\varepsilon, T, n)$:

$$\left|Q_t^i - Q_c^*\right|,$$

$$\left|\sum_{i=1}^{n} Q_t^i - nQ_c^*\right|,$$

for $i = 1, 2, \dots, n,\ t = 1, 2, \dots, T$; the bounds $B(\varepsilon, T, n)$ may be chosen so that for every $\varepsilon > 0,\ T \geq 1$,

$$\frac{B(\varepsilon, T, n)}{n^{0.5}} \text{ is uniformly bounded in } n,$$

and for every $T \geq 1$ and $n > 2$,

$$\lim_{\varepsilon \to 0} B(\varepsilon, T, n) = 0.$$

The main difference between the two cases is that the bound in the fixed-demand case is not a function of the number of firms n, while it is the case in the replication case. However, in both cases, when the deviation ε is sufficiently small, the cartel collapses and the ε- equilibrium will be the same as the static Cournot-Nash equilibrium effectively. Also, Radner (1980) shows that for any fixed ε and number of periods T, the cartel cannot survive at all if the number of firms n is sufficiently large in the replication case, while it is irrelevant for the survival of the cartel in the fixed-demand case.

Hypotheses

Casual observations above have provided us with the general direction that the price became higher and the quantity decreased slightly after the 2011 Thailand floods. Thus, we propose the following hypotheses that could explain the mechanism that brought the higher price and slightly lower quantity.

Hypothesis I: The 2011 Thailand floods caused a shift in the (inverse) demand function, in particular, α went up.

Hypothesis II: The 2011 Thailand floods triggered the formation of a de facto cartel between Western Digital and Seagate (and possibly with Toshiba, too).

We claim that these two hypotheses hold simultaneously for the current HDD industry. Hypothesis I is simple. Since the Cournot-Nash equilibrium price is $P^\wedge\_c=(\alpha + nc)/(n + 1)$ and the Cournot-Nash equilibrium firm production level is $Q^\wedge\_c= n/(n + 1)\cdot(\alpha - c)/\beta$, an increase in α will bring both the price and the production level higher. This means that Hypothesis I alone is unable to offer a consistent prediction with the actual observations, i.e. a higher price level and a lower production level.

As for Hypothesis II, there are two separate cases possible: the fixed-demand case and the replication case (or a more generic case in which the industry-level demand is a function of the number of firms). In the fixed-demand case, the difficulty of forming a cartel is independent of the number of firms. Thus, that the market consolidation happened almost simultaneously at the time of the Thailand floods through Seagate's acquisition of Samsung's HDD business and Western Digital's purchase of Hitachi's HDD business should be irrelevant to the formation of cartel, and the shock due to the Thailand floods is the only trigger for the formation. In contrast, in the replication case (or a more generic case), the market consolidation would have made the formation of the cartel easier.

In the fixed-demand case, the cartel price will be higher than the Cournot-Nash equilibrium price, and each firm's production will be fewer than the Cournot-Nash equilibrium production level. In the replication case, the decrease in production will be even greater since a smaller number of firms in the industry directly decreases the industry-level demand for and production of the product, while the prediction about the price is essentially the same as in the fixed-demand case. Thus, the observed facts, i.e. the higher price level and lower production level sustained after the 2011 floods may be explained by Hypothesis II in both fixed-demand and replication cases, i.e. whether or not the aggregate demand is a function of the number of firms does not matter with this regard.

Discussion

We saw above that a shift in demand alone would not be able to explain the observed behaviour of price and quantity after the 2011 Thailand floods, but a formation of a de facto cartel would be needed to explain the behaviour. Also, unless the industry-wide demand is independent of the number of firms within the industry, Radner (1980) showed that it is easier to sustain a cartel when there are fewer firms. Thus, it may well be that the ongoing consolidation of the HDD industry before the floods paved the way for a formation of a cartel with the floods acting as a trigger for it.

The fact that the average price and the gross margins of both Western Digital and Seagate rose substantially after the floods suggests that industries with fewer players may act collusively to exploit the temporary supply shortage caused by a natural disaster. Thus, natural disasters may induce a welfare loss due to collusive behaviours of firms, causing further losses in addition to the direct losses.

However, to show that HDD firms indeed formed a cartel in the aftermath of the floods require a more detailed empirical analysis based on micro data. In so doing, we need to evaluate the scale of the price pass-through to the clients, which corresponds to an increase in α in our model. Also, we need to measure the possible increase in the market power of the firms after the floods. These two effects need to be isolated so as to claim that a de facto cartel was indeed formed. To this end, the industrial organisation literature on the measurement of market power and cartel should be followed closely, for instance, Stigler (1964), Salant (1976), Bresnahan and Reiss (1991), Nevo (2001), and a survey by Andrade et al. (2001).

Implications

Risk Prevention Incentives and Moral Hazard

We have seen above that natural disasters may not cause losses to directly affected firms but may even benefit some firms. If a price rise follows a disaster as a result of a shift in the demand function or by a formation of a cartel, the costs of natural disasters would not be borne by the directly affected firms. Instead, their clients, consumers, and taxpayers pay the costs. Also, if a natural disaster triggers a shock to the industry so that a cartel is formed, there will be efficiency/welfare loss to the economy as a whole, which provides rent to the directly affected industry and welfare losses to other parties. Although it is not obvious if firms believe ex ante that they might benefit from natural disasters, this is still potentially a reason for such firms to spare investment in risk prevention. Also, firms would pay no particular attention to potential natural disasters in determining locations of factories if they believe no large losses would be incurred from natural disasters, but would instead benefit from them. Thus, a perverse incentive may have been given to firms; thus, serious moral hazard issues may arise. Our analysis therefore calls for two significant questions:

(a) Who incurs losses or damage from natural disasters?
(b) How and who should bear the costs of risk prevention against natural disasters?

In the case of the HDD industry, the answer to the first question appears to be the clients of the HDD industry, possibly including the end users, although this requires a further investigation into the structure of the chains involving the HDD industry, both upwards and downwards. The first best solution to the second question would be to design an incentive mechanism so that the HDD industry would be given incentives to invest in risk prevention, i.e. internalise the costs to the HDD industry. However, this is not straightforward because of the global nature of the industry. Direct interventions by the government such as Thailand's that force the HDD industry to invest in risk-prevention measures may well lead to relocation of the industry to other countries. Thus, it is unlikely that such legislation could be brought forward. Thus, to improve resilience against natural disasters: (1) a public policy that directly prepares for natural disasters should be implemented, e.g. conduct detailed geographical surveys to develop extensive hazard maps; implement better land use planning; improve infrastructure such as drainage system, dikes, and power grids with back-ups; and (2) incentives should be provided to firms to invest in risk prevention. To this end, one possible policy is to grant tax breaks or advantages if the firms make such investment. Such a preferential set-up is a common practice to invite foreign firms to invest in factories, but a similar arrangement should be put in place to incentivise investment in risk prevention.

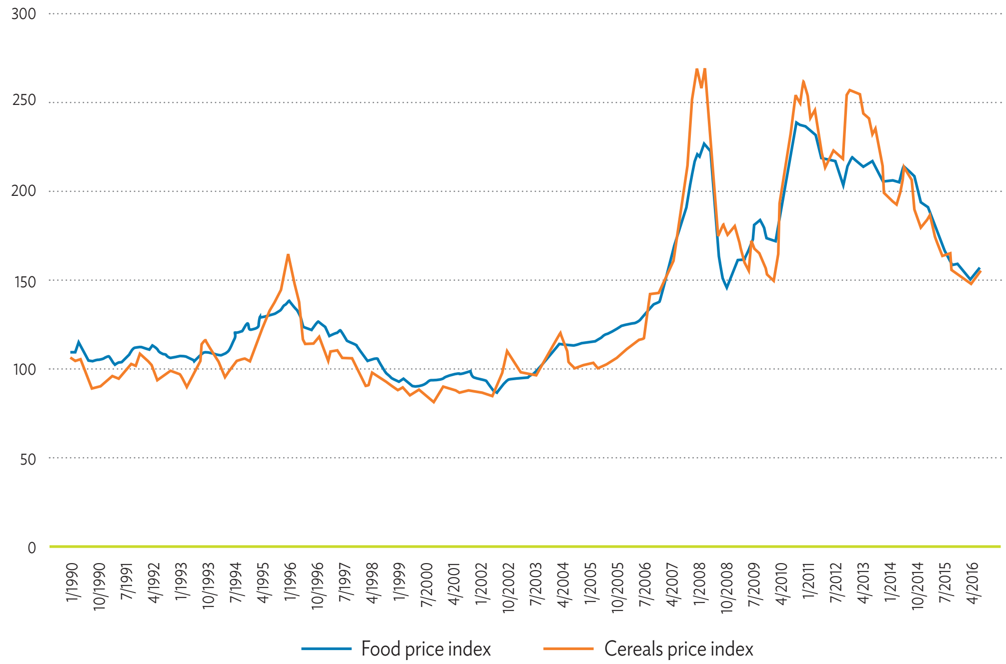
Implications for Agriculture

Agricultural production involves a variety of price and yield risks which appear to be prevalent, especially amongst small-scale, poor farmers in the semi-arid tropical areas in developing countries. Stakeholders in the agricultural sector adopt risk management strategies to smooth the income stream before risks or uncertainties unfold, which can be defined as activities for risk mitigation for and reduction in income instability. Farmers have traditionally managed agricultural production risks by crop diversification, inter-cropping, flexible production investments, the use of low-risk technologies, and special contracts such as sharecropping. Also, interlinked contracts amongst workers, producers, traders, and businesses have been widely observed in agriculture. However, it is often difficult by nature to adopt proper risk management strategies against natural disasters because they are typically rare events or, even worse, they are sometimes unforeseen. Accordingly, even if people adopted a variety of risk management strategies, a disaster can happen unexpectedly, causing serious damage to the welfare of those involved in the agricultural sector. For example, crops, livestock, farmland, and facilities may be destroyed or damaged by a natural disaster at an unprecedentedly large scale. Against such unexpected natural disasters, ex post risk-coping will be necessary so as to reduce profit fluctuations involving a variety of transactions in goods, labour, and credit markets. Moreover, formal insurance policies including index insurance contracts have been attracting wide attention as an effective financial instrument against covariate shocks arising from natural disasters. Index insurance contracts are written on specific events such as drought or flooding with specific attributes such as location, severity, etc. As such, index insurance involves a number of positive aspects: they can insure against aggregate events (i.e. events involving macro risks); affordable and accessible even to the poor; easy to implement and can be privately managed; and much less affected by moral hazard, adverse selection, and high transaction costs that have plagued conventional agricultural insurance policies such as crop insurance schemes. The World Bank and other institutions have been piloting weather-based index insurance contracts in Morocco, Mongolia, Peru, Viet Nam, Ethiopia, Guatemala, India, Mexico, Nicaragua, Romania, and Tunisia. Since natural disasters are typically an aggregate event, index insurance is thought to be an appropriate instrument to combat them. Nevertheless, natural disasters frequently involve highly covariate risks, which cannot be diversified within a country. Accordingly, the insurers may well need to rely on the international reinsurance market, although the capacity of the reinsurance market is limited. Also, recent studies show that the extent of international risk-sharing remains surprisingly small when the overall effectiveness of mutual insurance across national borders is measured.

Vertically Integrated Agricultural Businesses

Year 2008 is recorded as the year of a global food crisis: wheat and corn prices tripled and the price of rice increased fivefold between 2005 and 2008 (National Geographic, 2009). The global food prices spiked again in 2011 for the second time in 3 years (World Bank, 2016) as we can see from Figure 8 of the Food Price Index and Cereal Price Index compiled by the Food and Agriculture Organization (2016). The Food Price Index is composed of the average of five commodity group price indices: meat, dairy, cereals, oil, and sugar price indices. The Cereals Price Index consists of different grain indices such as 10 different wheat price quotations, one maize export quotation, and 16 rice price quotations, where rice quotations are combined into three groups of Indica, Japonica, and Aromatic rice varieties. Large spikes in global food prices led to reduction in real income and consumption levels of households, resulting in poverty. According to the World Bank (2012), an estimated 105 million people were pushed into poverty in low-income countries in 2007 and 2008, necessitating emergency supports for farming inputs, feeding programmes, and other safety net programmes. It should be noted that these price hikes stimulated political movements in a number of countries.

Figure 8: Global Food Price (Monthly real price, 2002-2004=100)



Source: Food and Agriculture Organization, 2016.

While price hike is a signal of excess food demand, market mechanisms behind the global food crisis have been under-investigated. To bridge this gap in the literature, we discuss the implications for agriculture of our analysis on the case of the HDD industry. To this end, we compare the players that are involved in the two sectors. The HDD industry itself is an oligopoly and their (upwards) suppliers are parts and component suppliers, i.e. firms, while there are four market segments amongst their clients (see, for instance, Western Digital, 2014): personal computers, enterprises, consumer electronics (mainly digital video recorders, game consoles and video recording systems), and branded products (external drives for home and small offices). Thus, the clients include both consumers and firms. In contrast, the majority of producers in agriculture are small farms although there are vertically integrated agriculture businesses too. Thus, the small producers would not have the market power unlike the HDD manufacturers, while the vertically integrated agricultural businesses may be similar to the HDD manufacturers. The middle of the stream before reaching consumers, the end users, is essentially corporate, however.

Thus, for the vertically integrated agriculture business, similar incentives may well hold as the HDD industry. Also, the corporate sector in the middle of the stream may exert market power or form a cartel. To be more specific, they may buy produce from the small suppliers at lower prices than ones that may reflect the costs of risk prevention or the potential costs of risk or uncertainty of natural disasters, and they may also sell produce to consumers at higher prices than the prices that would be observed in perfect competition, either due to oligopoly or by forming a cartel. Thus, the true costs of natural disasters or risk prevention may not be reflected in the prices for the transactions between producers and the corporate middlemen, while the corporate middlemen may enjoy higher profits from the occurrence of natural disasters against the consumers just as the HDD industry did.

The possible distortions due to the larger market power held by the corporate sector in agriculture may well be aggravating because of the furthering of globalisation of the sector: the total value of the global agricultural products exports grew from US$550.8 billion in 2000 to US$1,765.4 billion in 2014 (World Trade Organization, 2015). This makes the issue more difficult to be resolved because investment in risk prevention funded by the taxpayers may not bring sufficiently large benefits to the country due to the fact that the corporate sector can easily change the sources of supply across countries. In other words, the corporate sector can free ride the benefits of risk preventions and may also benefit from natural disasters when the agricultural production is hit by natural disasters as we saw above for the HDD industry.

Thus, to enhance risk prevention in disaster-prone areas, we need to consider the incentives of the corporate sector that may exert market power as in the case of the HDD industry. To this end, the policy recommendations for the HDD industry essentially hold the same for agriculture: (1) implement a public policy that directly prepares for natural disasters, e.g. conduct detailed geographical surveys to develop extensive hazard maps; implement better land use planning; improve infrastructure such as drainage system, dikes, and power grids with back-ups; and (2) provide the corporate sector with incentives to invest in risk prevention. The second point requires more detailed and careful considerations to design and implement incentive mechanisms as the structure of the agricultural sector is more complicated than the HDD industry.

Conclusion

This paper examined the possible effects of the 2011 Thailand floods on the HDD industry. Contrary to the common idea that the firms hit directly by floods are victims, the major HDD firms benefited instead from the floods by maintaining a higher price or gross margins than before the floods. This implies that firms expecting to benefit from natural disasters may have perverse incentives regarding investment in risk prevention. We also found that the industry-wide shipment has become consistently lower than what it was before the floods, which cannot be explained by the shift in demand. The combination of higher price and lower quantity suggests that the floods may trigger a formation of a cartel, i.e. the firms act collusively, according to the predictions of our theoretical framework based on Radner (1980). Cartel formation may well be easier when the industry is more consolidated. Thus, the degree of market concentration may be an important factor that drives incentives to invest in risk-prevention measures.

Based on the analysis of the HDD industry, we discussed the implications for the agricultural sector. The basic recommendations are essentially the same as those for the HDD industry, i.e. (1) implement a public policy that directly prepares for natural disasters, and (2) provide the corporate sector with incentives to invest in risk prevention. The key issue is the market power held by the corporate sector since it may well cause distortions in the risk-prevention efforts and the allocation of its burdens.

References

Andrade, G., M. Mitchell, and E. Stafford (2001), 'New Evidence and Perspectives on Mergers', *Journal of Economic Perspectives*, 15, pp.103–20.

Bresnahan, T.F. and P.C. Reiss (1991), 'Entry and Competition in Concentrated Markets', *Journal of Political Economy*, 99, pp.977–1009.

Food and Agriculture Organization (2016), Foodpriceindex http://www.fao.org/worldfoodsituation/foodpricesindex/en/

Fuller, T. (2011), 'Thailand Flooding Cripples Hard-Drive Suppliers', *The New York Times*, 6 November 2011. http://www.nytimes.com (accessed 13 August 2015).

Green, E.J. and R.H. Porter (1984), 'Noncooperative Collusion Under Imperfect Information', *Econometrica*, 52, pp.87–100.

Levenstein, M.C. and V.Y. Suslow (2006), 'What Determines Cartel Success?', *Journal of Economic Literature*, 44, pp.43–95.

Ministry of Economy, Trade and Industry (2012), 'White Paper on International Economy and Trade'.

National Geographic (2009), http://ngm.nationalgeographic.com/2009/06/cheap-food/bourne-text

Nevo, A. (2001), 'Measuring Market Power in the Ready-to-Eat Cereal Industry', *Econometrica*, 69, pp.307–42.

Radner, R. (1980), 'Collusive Behavior in Noncooperative Epsilon-Equilibria of Oligopolies with Long but Finite Lives', *Journal of Economic Theory*, 22, pp.136–54.

Salant, S.W. (1976), 'Exhaustible Resources and Industrial Structure: A Nash-Cournot Approach to the World Oil Market', *Journal of Political Economy*, 84, pp.1079–94.

Stigler, G. (1964), 'A Theory of Oligopoly', *Journal of Political Economy*, 72, pp.44–61.

Western Digital (2014), 'Annual Report, 2014'.

World Bank (2012), *Thai flood 2011: rapid assessment for resilient recovery and reconstruction planning*. http://go.worldbank.org/F28Z012480

World Trade Organization (2015), *International Trade Statistics 2015*.