1. INTRODUCTION

This chapter begins with a description of the research background, the motivation and the objectives of the study, and then goes on to provide an overview of this dissertation before concluding with an illustration of our study flowchart.

1.1 Background and Research Motivation

A ‘supply chain network’ (SCN) comprises of considerable interdependencies and interactions between different agents and processes (Surana, Kumara, Greaves, & Raghavan, 2005). Within a dynamic environment, the strategies and objectives of such supply chains are continually shifting as network managers strive to achieve better performance. Managing such complicated SCNs, as well as their shifting strategies and objectives, is a challenge that must be constantly faced by supply chain agents; thus, over recent years, there has been a general shift in focus in research into supply chain management (SCM) towards greater consideration of the issues associated with adaptation to changes within a complicated global network (Pathak, Day, Nair, Sawaya, & Kristal, 2007).

Within the overall analysis of such complicated global networks, ‘complex systems theory’ (CST) is generally applied as a perspective for conceptualizing and modeling dynamic phenomena; such an approach is invariably adopted with the support of certain other theories within the contexts of organizational change, social network analysis and SCN evolution. A ‘complex adaptive system’ (CAS) represents one specific class of CST as a whole, and also provides a method of analysis which focuses on the associated network agents (Anderson, 1999; Morel & Ramanujam, 1999).

The evolution of agent-based supply chains has already been fully described within the extant literature in terms of a CAS; that is, under the presumption that organizations across different tiers along a supply chain continue to interact and behave as a unified agent with regard to the exchange of information and physical goods, then a SCN can be characterized as a CAS (Holweg & Pil, 2008). Therefore, by regarding a SCN as a CAS, we can identify the ways in which such networks interact with the dynamic environment in which they operate, within which, the degree of 'fitness' is an aggregate outcome arising from the willingness of agents to adapt to new conditions (Choi, Dooley & Rungtusanatham, 2001).

Three forces are examined here, comprising of 'environment', 'co-evolution' and 'internality' (Choi et al., 2001). Based upon such examination, we can select the appropriate coordinating mechanism in accordance with the current state of the environment and current strategy rules. These strategy rules indicate that under certain situations, the adoption of a coordination strategy is highly recommended (Ghijsen, Jansweijer, & Wielinga, 2008), with such coordination including the sharing of information and resources, as well as enhancements to producer and consumer relationships.

As a supply chain proceeds along its evolutionary path, any discussion on the underlying forces of the changes in the supply chain will necessarily focus on the various agents adapting to their changing environment; thus, such forces comprise of both external and internal factors (Morel & Ramanujam, 1999). The external factors include information technology (IT), as well as the attributes of consumption, regulation, globalization and consolidation, all of which will give rise to reactions from the various agents within a CAS. Such reactions will involve, for example, the formation of new patterns, rules and types of behavior. The outcomes arising from such network evolution are the achievement of enhanced performance through an increase in fitness amongst the associated agents. This degree of fitness is characterized as the performance of a SCN.

In negotiations and transactions between supply chain members, such as suppliers, manufacturers, distributors and customers, the tendency in the past has been to establish arm's-length relationships; however, over the years, significant changes have occurred with regard to the evolutionary process of supply chains, leading to a discernible shift from competition to cooperation, coordination, and ultimately, collaboration (Spekman, Kamauff, & Myhr, 1998). Several of the prior studies provide comparative analyses of supply chains based upon the differences between competition and collaboration (Lamming, 1993; Spekman et al., 1998; Humphreys, Shiu, & Chan, 2001), with adversarial competition generally being found to be the fundamental strategy, and the primary focus being placed upon price negotiations and the activities of individuals (Humphreys et al., 2001).

It has, nevertheless, also become clear that, in terms of improvements in performance, where the participants are now more prepared to consider the total benefits to the supply chain as a whole, cooperation, coordination and collaboration clearly outperform competition. Thus, within the overall evolutionary process, the power has subsequently shifted from suppliers to customers (Vargo & Lusch, 2004), with IT playing an enabling role in supply chain coordination by enhancing the level of information sharing amongst the supply chain members (Gosain, Malhotra, & El Sawy, 2005; Lee & Kumara, 2007).

Recent years have therefore witnessed the pursuit of several coordinating initiatives aimed at enhancing the mutual benefits of all the parties involved within a supply chain whilst also improving overall performance. Compelling evidence has been provided to show that the efficacy of IT has positive effects on supply chain performance, with the adoption of e-auction mechanisms also bringing additional benefits to both buyers and sellers (Claro, Claro, de O., & Hagelaar, 2006). Such benefits include the pooling of potential suppliers and buyers, a general increase in annual sales, the ability of buyers to secure competitive purchasing prices and an increase in the visibility of information (Hartley, Lane, & Hong, 2004).

In particular, the adoption of IT systems can lead to a reduction in transaction costs, the shortening of order cycle times and increased operational efficiency (Huang & Iravani, 2005; Klein, 2007; Barratt & Oke, 2007; Chen, Yang & Li, 2007), whilst also eliminating product wastage losses (Hartley et al., 2004). Thus, when a SCN is recognized as a CAS, it is clear that the forces triggering the evolution of the SCN include both external conditions and internal factors, with such evolution being successful only if it leads to an increase in the degree of fitness amongst the associated agents (Morel & Ramanujam, 1999).

1.2 Research Objectives

Our primary aim in this study is to identify the CAS paradigm; this is of particular relevance to any examination of supply chain evolution. On the one hand, since a SCN is conceptualized as a CAS, the theoretical propositions on SCM in this study are developed from a perspective of CAS and IT. If IT, as an external condition, is adopted within a SCN, it will trigger the evolution of the supply chain, ultimately leading to the enhanced performance of the SCN.

By adopting a case study methodology, based upon a longitudinal approach, we can effectively determine the overall evolutionary process of the supply chain examined in the present study. We then go on to further verify the improvements in performance by selecting certain appropriate indicators based upon a review of the extant literature. This study therefore contributes to the extant literature by testing the efficacy of the various indicators through our analytical methodology.

The cut-flower industry in Taiwan has gone through some major changes over recent years; and indeed, the evolutionary phenomena have become increasingly apparent throughout Taiwan's cut-flower supply chains. We therefore set out in this study with the primary aim of describing the evolutionary process of supply chains, per se, and then go on to specifically examine the ways in which the evolution of the supply chains has been achieved in Taiwan's cut-flower industry through the setting up of the e-auction mechanism and the WISH system.

Five auction houses, Taipei Auction House (TPAH), Changhua Auction House (CHAH), Tainan Auction House (TNAH), Taichung Auction House (TCAH) and Kaohsiung Auction House (KHAH) provide the trading platforms for growers and retailers using auction clock transactions based upon the Dutch auction mechanism. This mechanism for the coordination of all auction transactions is determined in conjunction with the effective determination of prices and quantity setting, along with the coordination of all production processes, flower categories and logistical operations.

In order to facilitate our examination of the changes relating to supply chain evolution, we first of all divide the overall evolutionary process into three stages, comprising of the 'supplier-driven' stage (Stage 1), the 'retailer-driven' stage (Stage 2) and the 'e-system -driven' stage (Stage 3). The forces triggering the changes during each of these stages are identified as the interactions between external conditions and internal factors. Our examination of the case study of the cut-flower supply chain in Taiwan essentially aims to seek out evidence on these evolutionary forces, with the reaction of agents and the subsequent impact on general aggregate outcomes indicating the performance of the SCN.

Within our in-depth exploration of SCM during these three distinct stages, particular emphasis is placed upon the adoption of IT, since this is seen as playing an enabling role in SCM; thus, through our observations of the evolutionary path, we also demonstrate that IT systems are already being widely applied to facilitate information pooling and sharing. Indeed, such IT systems can be characterized as the intervention of external factors to trigger further evolution of a SCN.

Finally, we go on to demonstrate the evolutionary outcomes in the three distinct stages through our empirical analyses of the effectiveness of IT, using time-series data collected from the Wholesale Information Sharing Hotline (WISH) system.[1] The indicators representing the performance of SCNs are selected from our review of the extant literature.

Although the relative issues from the above discussion already exist as separate areas of research in various industries – such as the evolution of supply chains from a perspective of CAS and IT – as yet, relatively little evidence has been presented on these issues. This is particularly the case for the degree of 'fitness' amongst the associated agents, which ultimately produces the aggregate outcomes. There is also relatively little evidence on any real-world example of supply chain evolution. Hence, this study sets out to fill these gaps within the extant literature.

1.3 Flowchart of Research and Overview of Dissertation

The remainder of this dissertation is organized as follows. Chapter 2 provides a review of the literature on the theoretical foundations of CAS, including the CST and CAS paradigms, SCM from a CAS perspective and the conceptualization of a SCN as a CAS, in an attempt to describe the evolutionary phenomena of a SCN. From an IT perspective, different types of IT systems are widely applied to SCM as the means of facilitating information sharing, as a result of which, there is obvious potential for improvements in SCN performance.

In Chapter 3, extracts are taken from the literature review in order to develop our conceptual framework and theoretical propositions; this chapter also provides a description of the methodology based on both macro- and micro-study perspectives. From a macro-study perspective, the research methodology adopted for this study is a case study with a longitudinal approach, whilst the methodology adopted for our research from a micro-study perspective includes the *t*-test, *F*-test and Granger causality test, as well as

[1] For comprehensive details of the WISH System, refer to: 140.113.58.186/cognos/cgi-bin/login.cgi.

co-integration analysis.

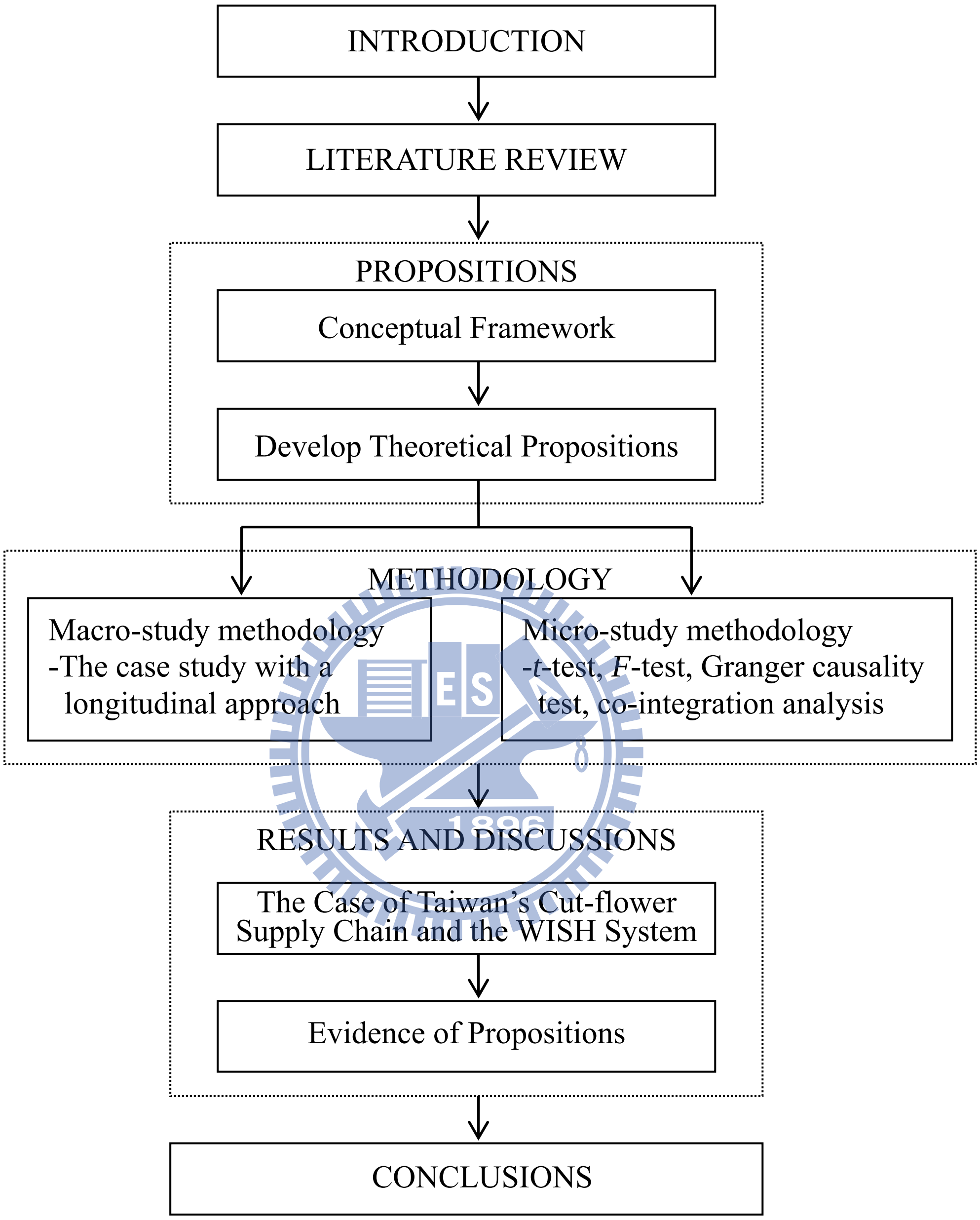

Figure 1. The study flowchart for this dissertation

The results are subsequently presented and discussed in Chapter 4, which begins with an examination of the case study of the cut-flower supply chains and the WISH system in Taiwan. The network form of the supply chain during each of the three stages is subsequently described, followed by the provision of evidence on the evolutionary phenomena, with our empirical findings ultimately providing strong support for our four propositions.

Finally, the conclusions drawn from this study are presented in Chapter 5, along with some concluding remarks, the limitations of this study, the potential direction for future studies, and some managerial implications. The flowchart for this dissertation is illustrated in Figure 1.

2. LITERATURE REVIEW

This chapter sets out to describe the current thinking on the theoretical foundations of CAS, the shift towards supply chain coordination through IT, and the network forms of the supply chain, thereby providing an overview of the current CAS and IT perspective on SCM research. Focusing on the issues relating to the evolutionary phenomena of SCNs, we provide a review of the related theories contributing to the theoretical propositions which are outlined in the subsequent chapter.

2.1 Theoretical Foundations of CAS

2.1.1 CST and CAS Paradigms

A complex system is defined as comprising of large numbers of interactive agents, or entities (Simon, 1996), with a total of six important insights and well-defined descriptive characteristics having been provided on such complex systems within the prior studies (Anderson, 1999; Morel & Ramanujam, 1999). These characteristics are: (i) a dynamic system does not reach a fixed-point or any cyclical equilibrium; (ii) the evolutionary processes revolve around discernible patterns of attractors, representing a limited area within a system which never departs; (iii) the behavior of agents between the various evolutionary processes is quite sensitive to small changes in initial conditions to follow an extremely diverse path; (iv) given that the interconnection and feedback loops involved in complex systems are difficult to elucidate, essentially because descriptions are necessary on a multiplicity of scales in order to identify how the emergent properties arise, reductionism and holism are complementary strategies in analyzing such systems; (v) complex patterns arise from the adherence by the various interactive agents to certain simple rules; and (vi) complex systems exhibit self-organizing behavior evolving towards order, and in so doing, thereby displace disorder.

The interdisciplinary field of CST has been applied to the analysis of dynamic systems over several decades as a perspective on CST aimed at conceptualizing and modeling dynamic phenomena; however, the process has advanced still further over more recent years, benefiting from other theories within the context of organizational change, social network analysis and SCN evolution. The CST paradigm comprises of CAS, self-similarity and fractals, self-organized criticality and self-organization (Morel & Ramanujam, 1999).

Based upon the CAS paradigm, CST systems are invariably modeled by researchers as interactive adaptive agents, with the potential utility of such CAS representing one specific class of CST with the capability of providing new ways of simplifying the overall complexity of systems (Anderson, 1999; Morel & Ramanujam). Such systems are characterized under four elements, comprising of 'interactive and adaptive agents with schemata', 'self-organizing networks sustained by the importation of energy', 'co-evolution to the edge of chaos', and the 'evolution of the system based upon recombination' (Anderson, 1999).

As regards the key element of 'interactive and adaptive agents with schemata', the CAS models focus on an investigation into the ways in which changes in the decision rules affect agents within a system in terms of the 'fitness' arising amongst such agents to produce the aggregate outcomes. Such decision rules are characterized as either 'blueprints' or 'schemata'. The blueprints are the images of the environment which capture the salient complexity of the system (Simon, 1996), whilst the schemata arise from condensation of environmental regularities, with such schemata competing against each other within the system (Gell-Mann, 1994a).

The schemata of agents are often modeled as a set of rules, with the fitness function representing the best performance objective, essentially in terms of a comparison with the outcome of each decision opportunity. The behavior of each agent is dictated by a specific decision rule which explains what action the agent will take at time t, given the perceived environment at either time t, or at time $t-k$ (if the theoretical considerations suggest the application of a lag structure). Different agents will potentially have the same rule when they are both dependent upon a common goal for the same fitness function (Anderson, 1999).

As regards 'self-organizing networks sustained by the importation of energy', such systems comprise of interactive actors naturally generating a stable structure through the application of rules. The application of such rules can determine the state of the system; indeed, systems actually self-organize, since we can observe the emergence of patterns and regularity with autogenesis. Thus, self-organization is essentially the natural result of non-linear interactions, wherein interactive entities combine to create a very simple structure.

The phenomenon of self-organization occurs only in open systems, essentially because the energy is imported from the outside. For example, an organizational system can be identified as a 'dissipative structure' which arises from thermodynamic equilibrium; thus, such a system is maintained by energy (Anderson, 1999). The pattern of interactions within a network is also sustained by the continuous injection of energy. Such energy within a supply chain arises from motive members, coordinating mechanisms and the reconstruction of the supply chain, with the motive members being the interactive agents who can be either tightly or loosely coupled.

Turning to the element of 'co-evolution to the edge of chaos', within the extant CAS theories, the presumption is that the adaptation of a system to its environment emerges from the adaptive effects of individual agents attempting to improve their own degree of 'fitness' (Anderson, 1999). The landscape of agent behavior is continually shifting, essentially because the fitness of individual agents is largely dependent upon the choices of other agents which will ultimately lead to further adjustment in their own behavior.

Kauffman (1995) suggested that if small changes in the behavior of agents were to lead only to small cascades of co-evolutionary change, then the performance of the system could never be improved that much; however, a series of small changes in behavior may trigger an occasional huge co-evolutionary shift, which then allows the system to leap to higher fitness peaks through evolutionary refinement, ultimately leading to greater enhancements in the performance of the system.

In contrast to the argument of Bak (1996) and Kauffman (1995) suggested that a CAS naturally evolves to the edge of chaos as the natural outcome of evolutionary processes, with the fitness of the system ultimately being modified on the basis of the least-fit element. Despite the obvious differences in their lines of reasoning, Kauffman and Bak nevertheless both agree that a CAS does evolve to the edge of chaos (Anderson, 1999).

As regards the fourth element, the 'evolution of the system based upon recombination', it was argued in both Simon (1996) and Anderson (1999) that a CAS essentially comprises of nested hierarchies containing other CASs – with these subsystems themselves continuing to evolve – within which the various elements, such as agents with schemata, the strength of the connections and their fitness functions can also change over time. Thus, new elements may emerge over time to give rise to a new organizational structure.

A fundamental view of CASs is not only that local behavior should be allowed to generate global characteristics, but also that there is the possibility of altering the ways in which agents interact (Anderson, 1999); indeed, a CAS can evolve based upon the fact that either new agents are being continuously injected into the system, or that new schemata are introduced. Either of these factors will lead to the generation of a new form through the recombination of the various agents. With this issue in mind, Levinthal and Warglien (1999) noted that such recombination is a fundamental prerequisite for the adaptation of ‘rugged fitness landscapes’.

Within the bounds of SCM, the present study investigates the evolution of SCNs based upon consideration of the evolutionary forces facilitating the evolution of the supply chain, as well as an examination of such evolutionary dynamics based upon CAS theory. We begin with a discussion on the benefits for SCM from a CAS perspective, conceptualizing a SCN as a CAS in order to explore such evolution.

2.1.2 SCM in the Perspective of CAS

The evolution of agent-based supply chains has already been well described in terms of a CAS, with both Choi et al. (2001) and Pathak et al. (2007) recognizing that a supply chain network can be identified as a CAS through the provision of evidence showing that each of the detailed properties of a CAS can be contrasted with each of the characteristics of a supply network. Several propositions and suggestions contributing to SCM were addressed in both studies, with the supply network in Choi et al. in particular being framed and examined as a CAS under the three mechanisms of ‘environment’, ‘co-evolution’ and ‘internality’. Such an approach enables us to identify the ways in which networks interact with their dynamic environment, within which existing patterns accrued from such co-evolution can be identified, as follows.

2.1.2.1 Environment

The external environment of a CAS includes the general trends and changes that take place, as well as other disjointed entities which do not form part of the given CAS (Choi et al., 2001). The trends and changes are society, technology, economics, policy, law, culture, and so on, within which a CAS is enveloped. As regards the ‘other disjointed entities’, if a focal SCN is identified as the CAS, then its members are the agents, whilst any other members not in this SCN may be seen as part of the external environment. The nature of this environment is both dynamic and rugged (Choi et al.), with such dynamics essentially occurring within a CAS through the alterations made to the boundaries of the system either through additional connections amongst agents, or the elimination of any previous connections amongst them. Any change to a CAS will ultimately trigger further environmental changes (Choi et al.); thus, on the one hand, a CAS reacts to changes in the external environment, whilst on the other hand, it creates its own environment, thereby giving rise to further changes.

2.1.2.2 Co-evolution

Choi et al. (2001) demonstrated that co-evolution involves the mutual evolutionary processes which take place between the various agents within a CAS and its environment; these processes arise as a direct result of the interactions between the CAS and the environment, thereby creating dynamics from which certain patterns emerge, such as competition, cooperation or collaboration. Choi et al. argued that along the evolutionary path of a SCN, the goal of SCM is essentially the managerial importance deduced from the co-evolution, which necessitates a good understanding of how much should be controlled and how much should be allowed to emerge naturally, and appropriate strategies being developed in order to pursue this goal.

Managers must therefore attempt to adopt a suitable approach comprising of a balance between control and emergence, since mastery of this approach will undoubtedly lead to such managers outperforming those who elect to adopt either control or emergence in isolation (Choi et al., 2001). Clearly, many SCNs emerge naturally as opposed to resulting from any intentional design by an individual agent (Choi et al.). Nevertheless, Hanaki et al.

(2007) noted that through co-evolution, the emergence of cooperative behavior within environments was essentially attributable to the selection of best performance traders and the imitation of best-performing agents.

Conversely, however, other scholars suggest that coordinative behavior is founded on predetermined mechanisms of governments and incentives (Dyer & Nobeoka, 2000; Wathne & Heide, 2004), with such government mechanisms involved in SCNs providing applicable arrangements to create certain rules or norms. Clearly, the successful implementation of government mechanisms (such as contractual arrangements and common standards) can lead to greater efficiency, but it may also have negative consequences (such as a reduction in innovative activity). The incentive mechanisms referred to in Dyer and Nobeoka (2000) are the realizable benefits for all participants within a SCN, which will ultimately lead to other disjointed entities deciding to participate in such networks.

2.1.2.3 Internality

The internality of a CAS comprises of 'agents and schema', 'self-organization and emergence', 'network connectivity' and 'dimensionality' (Choi et al., 2001); these are described as follows: (i) within the first element, 'agents and schema', an agent may be represented by an individual, a project team, a division, an organization or an entire supply chain with the capability of establishing the mainstream behavior, whilst the schema possessed by agents refer to the norms, values, beliefs and assumptions involved in increasing the degree of 'fitness' between the members within a CAS; (ii) as regards 'self-organization and emergence', the latter characteristic, emergence, refers to the occurrence of new structures, patterns, properties or processes which are external to any interventions by a central controller within a CAS, as a result of which, a CAS is a self-organizing system (Anderson, 1999; Choi et al., 2001); (iii) 'network connectivity' is defined as a large number of interconnected agents representing the interrelationships within the network; and (iv) 'dimensionality' involves the degree of autonomy possessed by individual agents with regard to their behavior within the CAS. The various rules, standards or institutions represent controls which can effectively reduce the level of dimensionality, whereas a higher degree of autonomy leads to the overall magnification of dimensionality (Choi et al., 2001).

The merits of both complexity theory and CAS, in terms of their potential contributions to SCM, were further emphasized in the examination undertaken by Pathak et al. (2007), which provided several particular issues for potential future research on SCNs associated with our research questions. Surana et al. (2005) had previously developed both conceptual and computational tools in order to make new approaches possible for the modeling of the interactions between agents within a SCN so as to provide a better understanding of the complexity of such systems.

Thus, the modern approach to SCM research has essentially shifted towards greater emphasis on the consideration of issues such as the myriad relationships and phenomena characterizing SCNs, thereby taking into account the collective behavior of agents within integrated systems (Pathak et al., 2007). In the following sub-sections, we conceptualize a SCN as a CAS leading to the development of the theoretical propositions of this study.

2.1.3 Conceptualizing a SCN as a CAS

A supply chain involves both the upstream and downstream processes and activities that are reliant upon the interconnections between all firms, with value ultimately being produced in the form of the provision of products and services for customers (Christopher, 1998). One key element within SCM as a whole is the need for an understanding of the ways in which the configuration of a SCN is organized, with the three important aspects being the analysis of the network structure (such as the key members), the structural dimensions of the network, and the different types of process and relationship linkages (Lambert, Cooper, & Pagh, 1998).

Networks initially arise from the mutual interactions between a few firms (Thorelli, 1986), with a SCN being a self-organizing system in accordance with the viewpoints of each of the individual agents; these individual agents participate in a SCN due to localized choices to create probabilistic entities, including the selection of capable suppliers and sufficient confidence in on-time delivery of products to their buyers (Surana et al., 2005).

A vertical SCN comprises of at least two levels of relationship; that is, the relationship between a manufacturer and either a downstream retailer or an upstream supplier (Wathne & Heide; 2004). Indeed, a SCN is a complex network with enormous interdependencies and interactions between different agents and processes (Surana et al., 2005). In the framing of our SCM research in the present study, we also recognize a SCN as a CAS, with a number of contentions being discernible from the extant literature with regard to this CAS perspective, as follows.

Firstly, a SCN comprises of interactive members each of whom follow a set of decision rules, or ‘schema’. The structural dimensions of a SCN comprise of its horizontal structure (the number of tiers), its vertical structure (the number of members within each tier) and the agent’s horizontal position within the SCN (Lambert et al., 1998). At the higher levels of a SCN, each tier symbolizes a supplier, manufacturer, assembler, wholesaler, distributor, retailer or customer; however, within these tiers, there are also those physical entities that exist inside each tier at the upper level (Pathak et al., 2007). Agents will attempt to increase their degree of ‘fitness’ by reducing costs, enhancing quality and becoming more flexible, which will be reflected in their regular performance reports within the SCNs (Choi et al., 2001). As noted in the subsequent discussion on the best performance report, the common schema refer to the norms, values and beliefs possessed by the agents, which will ultimately lead to reduced transaction costs and an increase in communication efficiency (Choi et al.).

Secondly, similar to a CAS, a SCN is a self-organizing system. Such self-organization comes as a result of the interactions between agents and their adaptation to the dynamic environment, since individual agents participate in a SCN to create their potential traders based on localized decision-making (Choi et al., 2001; Surana et al., 2005). As evidence of this, we need only consider the case of Toyota, which, although known for its processes of effectiveness in creating and managing its knowledge-sharing network, is nevertheless unable to measure the depth and width of the network (Dyer & Nobeoka, 2000). In the case of a SCN, the organization of an overall network emerges by means of a spontaneous process; similarly, the scope of the SCN is unfathomable. Indeed, no one firm is able to more powerfully harmonize and control the totality of operations in such networks than any other firm (Choi et al.).

Thirdly, within a SCN, the main characteristics of the non-linear dynamics are regarded as the interrelated spatial and temporal effects. Choi et al. (2001) argued that the self-organization of any supply network will occur either in parallel or in a non-linear way; such an argument can be further applied to the case of a SCN. Surana et al. (2005) also revealed that a SCN invariably has a wide geographical distribution, and that it also has a characteristics feature of changing workloads and configuration over time, with such changes ultimately being contributed by the end-users (the ‘bullwhip’ effect). For instance, based upon the horizontal position of a focal firm within a SCN, a manufacturer selects a group of first-tier suppliers; however, in advance of its selection, a group of second-tier suppliers has already been connected to one of first-tier suppliers subsequently chosen by this manufacturer. It is therefore clear that a SCN tends to be a self-organizing phenomenon, where events occur in a non-linear way, involving interrelated spatial and temporal effects.

Finally, a SCN co-evolves to the edge of chaos, with the co-evolution of the system emerging in the 'rugged fitness landscape' (Anderson, 1999); this rugged fitness landscape involves the selection of conflicting degrees of 'fitness' which are, in some way, aggregated into a common degree of fitness. This degree of fitness represents either a common goal or the performance of the system, involving issues such as a reduction in inventory levels, an increase in fulfillment rates, and responsiveness to changing demand (Huang & Iravani, 2005; Klein, 2007; Barratt & Oke, 2007; Chen et al.; 2007).

In the real-world case of the automotive industry within the US, all of the automotive manufacturers, such as Ford, worked with their multiple suppliers during the 1970s and early 1980s to establish short-term contracts formed under a supply network configuration. The Japanese automotive companies subsequently went on to introduce an alternative network configuration comprising of a closed and long-run relationship with suppliers (Choi et al., 2001). The extremely successful Japanese version of supply management ultimately led to the US automotive firms totally restructuring themselves through consolidation; indeed, the structure of the supply network has clearly gone through radical changes.

We can therefore conclude that an occasional significant shift in co-evolution may generally be triggered by a cascade of small changes in behavior, although the small event which eventually triggers this huge change is extremely difficult to identify (Choi et al.); nevertheless, such a random huge change will allow the system to leap to a higher fitness landscape (Kauffman, 1995). The eventual change is readily identifiable and observable, and is seen as the ultimate causal event in the total reconfiguration and redefinition of the system.

2.2 The Shift towards Supply Chain Coordination through IT

The coordination of agents is defined as a process with the capability of effectively managing the interdependencies between various activities (Malone and Crowstone, 1994); the design of this process is based upon coordination mechanisms such as the sharing of information and resources, and enhancements to producer and consumer relationships (Crowston, 1997; Malone & Crowstone, 1994). Such coordination mechanisms are selected in accordance with the current state of the environment to formulate a set of strategic rules (Ghijsen et al., 2008); a major challenge to this is the deployment of effective coordinating strategies that will ultimately lead to adaptive, flexible and coherent collective supply chain behavior.

Group members have traditionally carried out their business based upon arm's-length relationships, with an emphasis on individual activities and restricted information sharing (Chen et al., 2007), and with such relationships invariably being based upon only a single transaction, focusing mainly on price negotiations and the guarantee of a constant supply (Humphreys et al., 2001). Nowadays, however, supply chain relationships essentially comprise of a flow from competition to cooperation and coordination, and ultimately, collaboration (Spekman et al., 1998).

Competition can be regarded as a network of firms competing with other firms along the entire supply chain (Spekman et al., 1998); thus, the focus in this stage is generally on independent and adversarial relationships. With the subsequent move to the stage of cooperation, it becomes necessary to ensure the effective integration of the functions of all of the interdependent units in order to successfully meet consumer needs. The coordination stage involves the further integration of workflows and information linkages between the trading parties.

Finally, the collaboration stage involves the highest level of intensity of this relationship, within which the trading partners integrate their major consumer processes to achieve their common, desired goals (Spekman et al., 1998; Claro et al., 2006; Matopoulos, Vlachopoulou, Manthou, & Manos, 2007). This final stage focuses on supply chain integration, joint planning, and technology sharing based upon mutual trust and commitment (Spekman et al., 1998).

Several of the prior studies have provided outline sketches of the critical differences between competition and collaboration, with many of these studies demonstrating that cooperation, coordination and collaboration generally outperform competition, particularly with regard to overall improvements in performance (Lamming, 1993; Spekman et al., 1998; Humphreys et al., 2001). The general approach to SCM has consequently shifted towards greater emphasis on the consideration of issues such as global optimization, thereby taking into account the benefits accrued from the supply chain as a whole, as opposed to the benefits that may be accrued by individual firms. As a result, customers now have much greater power and influence over supply chains than ever before (Fearne, 1998; Vargo & Lusch, 2004); the focus in SCM has, therefore, essentially shifted from supply management to demand management.

Nevertheless, in much of the extant literature, a tendency is revealed for continued exploration of coordination between trading parties along the same supply chain, albeit at different echelons. It is, however, clear that successful coordinating strategies within a SCN will necessarily involve a combination of core processes across different echelons and organizational boundaries (Cheung & Lee, 2002; Lee & Kumara, 2007; Disney, Lambrecht, Towill, & Van de Velde, 2008). The three elements of coordination that are generally seen as enablers capable of effectively enhancing performance are 'information sharing', 'decision synchronization' and 'incentive alignment' (Mentzer, Foggin, & Golicic, 2000; Simatupang & Sridharan, 2004).

A requirement therefore exists for all traders within the chain to recognize the need to embrace the types of IT systems that are now being widely applied to SCM in order to facilitate greater information pooling and sharing, as a result of which, there is obvious potential for improvements in operational performance. The incentives must, however, be properly aligned in order to support such extensive information exchange (Disney et al., 2008).

Over the past decade or so, coordination through IT has become the core mechanism amongst supply chain members; however, it has advanced still further over more recent years, with several initiatives, such as vendor-managed inventory (VMI) and the e-marketplace, having succeeded in enhancing such coordination (Cheung & Lee, 2002). Within the overall process of VMI, vendors manage the inventory levels of buyers; that is, vendors take the decisions on appropriate inventory levels within previously agreed polices and bounds (Simchi-Levi, Kaminsky, & Simchi-Levi, 2008).

In modern-day SCM, 'collaborative planning, forecasting and replenishment' (CPFR) can be further used to promote supply chain collaboration (Chen et al., 2007; Pramatari, 2007). The CPFR system, which was developed by the Voluntary Inter-industry Commerce Standards (VICS) is a supply chain collaboration initiative defined as a business practice combining the intelligence of multiple trading partners in the planning and fulfillment of consumer demand (VICS, 2004).

It is also clear that IT has played an important enabling role in supply chain coordination since it significantly reduces the costs of such coordination; indeed, many of the prior studies indicate that information sharing through e-business technology is a fundamental element of the deployment of coordination strategies in supply chains (Malone & Crowstone, 1994; Surana et al., 2005). As noted in both Swaminathan and Tayur (2003) and Klein (2007), e-business technology and the resultant enabled information systems, represent a business process which makes best use of the Internet to complete business transactions. Patnayakuni, Rai and Seth (2006) further confirmed that the integration of information flows is an essential element of supply chain coordination, with all parties involved being required to share transactional, operational and strategic data.

It was recently demonstrated by Disney et al. (2008) that a coordination scheme based upon a policy of replenishment can be achieved in a two-echelon supply chain; however, there is one major constraint, in that the supply chain members are required to share much of their information. Thus, other incentives must be applied in order to support such extensive information exchange, with the actual extent of information sharing being largely dependent upon the overall level of visibility (Barratt & Oke, 2007). Given the common aim of the ultimate achievement of effective supply chain coordination, the range of IT systems available to support such information sharing and visibility has expanded enormously.

2.3 Supply Chain Network Forms

Networks arise from the intensity of the mutual interactions between two or more firms, with such intensity being largely dependent upon the quantity, quality and type of interactions between agents; this indicates whether a network is loosely or tightly bound (Thorelli, 1986). An appropriate classification of network forms was provided by Achrol and Kotler (1999) as 'internal', 'vertical', 'inter-market' and 'opportunity' networks. Of these, a supply chain can be identified as a vertical network, within which a group of diversely functional firms are organized around a focal company which monitors and manages the critical contingencies occurring within a particular industry.

The configuration of a SCN is analyzed from three different aspects, 'key members', 'structural network dimensions' and 'different types of process and relationship linkages'

(Lambert et al, 1998). The structural dimensions of a supply chain comprise of the horizontal structure (the number of tiers), the vertical structure (the number of members within each tier) and the agent's horizontal position (Lambert et al., 1998). A vertical SCN comprises of at least two levels of relationship (Wathne & Heide, 2004), with a SCN actually representing a complex network involving enormous interdependencies and interactions between agents and processes (Surana et al., 2005). The network resources offered by members are their valuable information, all of which is made available to every firm, and which clearly has a significant influence on firm performance (Dyer & Hatch, 2006).

Since the driving force within networks has shifted from producers to customers, the focus has also moved from tangible to intangible resources, with these intangible resources including information sharing, the mutual creation of value, and ongoing relationship connections (Vargo & Lusch, 2004). Indeed, as the specialized skills of the agents within the network rapidly and continuously adapt to changes in the dynamic environments, there will be a shift in the coordination mechanism from a production orientation to various marketing orientations (Achrol & Kotler, 1999).

The network form in the present study is characterized by agents cooperating through the e-auction system, with all of these agents being essentially reliant upon the frequent contacts between producers and retailers through their auction house interconnections, which ultimately give rise to the establishment of contractual relationships (Claro et al., 2006). This network therefore has the characteristic features of a CAS (Choi et al., 2001; Surana et al., 2005).

As noted above (in the theoretical foundations of a CAS), based upon the examination of both the CST and CAS paradigms, the analysis of SCM from a CAS perspective, and the conceptualization of a SCN as a CAS, this study adopts a CAS perspective to describe the evolutionary phenomena of SCNs. From an IT perspective, various types of IT systems are widely applied to SCM as the means of facilitating greater information sharing, as a result of which, there is obvious potential for considerable improvements in operational performance.

3. PROPOSITIONS AND METHODOLOGY

As noted in the earlier overview of this dissertation, this chapter proceeds with an explanation of the development of our propositions, from a perspective of CAS and IT. This will facilitate our observation and investigation of the evolution of SCNs, with our adoption of macro- and micro-based study methodology also being explained in sub-section 3.2.

3.1 Development of our Theoretical Propositions

Based upon the review of the prior studies in the previous chapter, in order to facilitate our research into the evolution of a SCN, the SCN in this study is characterized as a CAS. Within SCNs, the interactive agents adapt to the external changes by altering their noble decision rules and connectivity, with the outcome being identified as the performance of the SCN. Thus, we can describe the evolutionary forces and outcomes as follows.

3.2.1 The Evolutionary Phenomena of a SCN

Proposition 1 in this sub-section argues that: (i) the evolutionary process of a SCN comprises of evolutionary forces, involving the interactions between external conditions and internal factors; (ii) the evolutionary process is regarded as a repetitive sequence of these forces; and (iii) such evolution can be regarded as successful only if it brings about an increase in the degree of ‘fitness’ for the network agents. These elements are explained as follows:

3.2.1.1 External condition

External conditions involve society, technology, economics, policy, law and culture, which do not form part of the given SCN (Choi et al., 2001). Several studies have noted that external conditions, such as subtle changes over time in the attributes of consumption, stricter regulations and laws, globalization and consolidation, can each enhance the design and administration of supply chain relationships, thereby affecting the characteristics of transactions (Fearne, 1998; Hobbs & Young, 2000; Matopoulos et al., 2007).

However, environments have been identified as both shaping, and being shaped, by evolution, not only imposing new rules and norms that will ultimately alter the behavior, structures and patterns of agents within the SCN, but also being shaped by the evolution of the SCN, thereby triggering further changes in the environment. Within the floriculture sector of the Netherlands, for example, the dynamic changes that have taken place in the consumption attitudes of customers reveal their heightened concerns over issues such as product safety and environmental protection. The Milieu Programma Sierteelt (MPS) now offers certification and labeling services for both growers and traders, demonstrating real concern for environmental impact and a reduction in unsafe products.[2] Such mechanisms can further trigger substantial increases in the total quantity of flower purchases carrying the MPS certification label amongst customers. Therefore, agents may evolve over long time spans as they learn from their interactions and adaptation to dynamic environments.

3.2.1.2 Internal factors

The interactive members of SCNs are the agents, comprising of suppliers, manufacturers, assemblers, wholesalers, distributors, retailers and customers. Their decision rules can be characterized as the schemata accrued from condensation of the regular behavior patterns amongst these agents, including the norms, values and beliefs possessed by such agents that will ultimately lead to a reduction in transaction costs and an increase in communication efficiency (Choi et al., 2001). The behavior of each agent is dictated by a

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2 Refer to www.my-mps.com for comprehensive details on the Milieu Programma Sierteelt (MPS).

decision rule, with different agents potentially having the same rule when they are both dependent upon a common goal for the same fitness function.

The connectivity of agents is defined as a situation whereby the actions of a focal firm will have a greater influence on other firms based upon their interconnection. The myriad relationships existing between these agents are connected by tangible paths (telephone lines, electronic data interchange systems, and so on), as well as through other intangible channels (including information exchange and communication). By increasing the connectivity amongst the agents, the interrelationships between them are in turn advanced.

Any subsequent alteration in the behavior of agents (decision rules and connectivity) arising from external changes can lead to shifts in the fitness function of individual agents (Anderson, 1999). This fitness function represents the overall performance of the system; that is, the desired optimal state. However, such a fitness function is extremely difficult to identify since many local optimum levels will exist within the system, although it has been argued that the function is potentially determined by exploring past adaptations and market position, and by copying from other successful agents (Anderson). Any conflicting degrees of fitness amongst network members will eventually be aggregated into a common fitness level by the coordinating protocols (Surana et al., 2005), with this common fitness being selected in accordance with the current state of the environment and the current decision rules (Ghijsen et al., 2008).

As argued by Kauffman (1995), a random huge co-evolution may be triggered by a cascade of small events, which then allows the system to leap to higher fitness peaks through evolutionary refinement; however, small changes in the behavior of agents can only lead to small co-evolutionary changes, and as such, the performance of the system can never be improved that much. Therefore, the evolution of a SCN is not driven by any well-defined fitness function, but rather, by the accumulation of a series of small events

(Morel & Ramanujam, 1999).

In the evolutionary processes of a supply chain, a state at time t is the output of one application of decision rules; any subsequent change in the environment can trigger a cascade of changes in a SCN, which can ultimately result in the network moving away from a quasi-equilibrium state to an alternative state (at time $t+1$), which is far from equilibrium. The behavior patterns within the SCN will therefore switch from one attracter to another (Choi et al. 2001), and as such, the evolution of the supply chain is identified as a switch of attracters. A new attracter, with new agents and new schemata, is eventually introduced to generate a new network form by recombining all of the elements within the SCN (Anderson, 1999).

The driving forces leading to changes in SCNs therefore comprise of external conditions (such as changes in IT or the attributes of consumption, regulations and globalization) and internal factors (involving, for example, the formation of new decision rules and connectivity). The evolutionary dynamic forces responsible for the changes in the supply chain are a combination of external pressures and internal events, and this can only be successful if it leads to an increase in the degree of fitness (Morel & Ramanujam, 1999). Indeed, the evolutionary process for SCNs is regarded as a repetitive sequence of these forces amongst the various agents as they react to the external changes (Van de Ven & Poole, 1995). Through a combination of the above viewpoints, we present our first proposition in this study, as follows:

Proposition 1: (*a*) *The evolutionary forces within a SCN comprise of the interactions between external conditions and internal factors;* (*b*) *the evolutionary process is regarded as a repetitive sequence of these forces; and* (*c*) *such evolution can be regarded as successful only if it brings about an increase in the degree of 'fitness' amongst the network agents.*

3.2.2 Performance Improvements through IT

Based upon our earlier review of the literature on supply chain coordination through IT, it is clear that IT has played an important enabling role in SCM since it has significantly enhanced supply chain performance through greater information sharing and visibility. Such performance includes improvements in operational performance, reductions in inventory levels, increases in fulfillment rates and responsiveness to changing demand (Huang & Iravani, 2005; Klein, 2007; Barratt & Oke, 2007; Chen et al.; 2007). The adoption of e-auction mechanisms ensures the necessary enhancements to information sharing, whilst also bringing additional benefits to both buyers and sellers (Claro et al. 2006). These benefits include increased annual sales, reduced transaction costs, shortened order cycle times, increased visibility and efficiency, the achievement of competitive purchase prices and the pooling of potential suppliers (Hartley et al. 2004).

The increases in fulfillment rates and annual sales, as well as the pooling of potential suppliers are identifiers of the growth of the market, whilst the increase in visibility to reduce the uncertainty of both supply and demand identifies the stability of the market. Efficiency, in terms of operations and transactions, is identified through improvements to operational performance, reductions in both inventory levels and transaction costs, appropriate responses to changing demand, and shorter order cycle times. Therefore, as a result of the above benefits provided by the introduction of IT systems, we can identify the following three characteristics of 'growth', 'stability' and 'efficiency' as appropriate SCN performance measures.

3.2.2.1 Growth

According to the evaluations undertaken by Clark and Chatterjee (1999) and Gowrisankaran and Stavins (2004), the adoption of technology, and subsequent enhancements, can give rise to network effects to a significant extent, with positive increases in the network effects amongst network participants in turn enhancing both transaction quantity and market share; such positive network effects are defined as the benefits arising from the greater numbers of users. Riggins, Kriebel and Mukhopadhyay (1994) noted that suppliers can gain economic benefits from the increased market share when joining an e-system network initiated by a retailer. Thus, the setting up of an IT system is likely to lead to a significant increase in market share for all participants, essentially because positive network effects can be accrued through the greater numbers of users, thereby further broadening the overall market scale.

As a result of the promise of greater increases in revenue, firms have begun to engage in substantial investment in online auctions. Hartley et al. (2004) noted that those adopting an e-auction system achieved higher annual sales and substantially higher market share as compared to those who elected not to adopt such a system. Indeed, the introduction of an IT system can ultimately attract a wide variety of sellers and buyers to trade in products via the Internet. As a result of the accrual of positive network effects subsequently facilitating positive increases in transaction quantity, this will, in turn, foster the continuing growth of the market. The above discussion gives rise to the second of our propositions in this study, as follows:

Proposition 2: *If IT, as an external condition, is introduced into a SCN, this will bring about an increase in transaction quantity*.

3.2.2.2 Stability

The current trend in SCM is to try to leverage the benefits obtained through information sharing, thereby further improving performance; the adoption of IT has clearly made it easier for information to be shared amongst supply chain agents, and there can be little doubt that information sharing and visibility through the adoption of an e-system enhances the supply chain benefits. The adoption of e-auction mechanisms also brings benefits to both buyers and sellers (Claro et al. 2006), with organizations in general benefiting from the information pooling effect across two supply chains (Huang and Iravani, 2005). The benefits arising from the intervention of IT systems include the achievement of competitive purchasing prices for buyers and increased visibility of information (Hartley et al., 2004).

The loosely-connected characteristic of the agents within the e-auction system facilitates rapid responses to changes in the business environment when variability exists on both the supply and demand sides, and more specifically, when such variability can be amplified across a SCN (Gosain et al., 2005). The range of IT systems currently available to provide appropriate support to information sharing and visibility has the effect of reducing such variability, with price being an important indicator used to examine both the stability of a system and the visibility of the information contained within it.

According to the argument of Engelbrecht-Wiggans, Haruvy, and Katok (2007), within reverse auctions, if the number of suppliers is small and the correlation between cost and quality is low, the buyer would be better off with a 'price-based' mechanism; however, as a result of these assumptions not being supported, a buyer promises to award the contract to the mediator with the lower purchase price. As regards the willingness to pay amongst consumers in online auctions, there will be a decline in price if other similar items are concurrently listed with the focal item, or if there are more extensive sites on which to surf and bid (Chan, Kadiyali, & Park, 2007). Sellers in an e-auction environment will consider setting a lower price in order to successfully trade their merchandise with buyers; consequently buyers can secure competitive purchasing prices, and as a result, there will be a general tendency towards a decline in prices.

This line of reasoning is applied primarily to interpret the setting of effective pricing through information sharing, with the test for co-integration being based upon nonstationary time-series data (Engle & Granger, 1987). Indeed, the adoption of such a co-integration analysis in order to test for the pooling or non-pooling of information between supply chains during distinct periods could represent a valuable method of assessing both information visibility and long-run equilibrium.

IT intervention within a SCN will therefore increase the overall visibility of information amongst agents, leading in turn to a tendency towards price declines and stability, with the price exhibiting long-run equilibrium. From a combination of all of the above, we state our third proposition, as follows:

Proposition 3: *If IT, as an external condition, is introduced into a SCN, then (a) there will be reductions in the volatility of price and (b) decreases in the prices, (c) greater visibility in pricing, and (d) better long-run equilibrium pricing.*

3.2.2.2 Efficiency

All agents within a SCN must recognize the need to embrace the types of IT systems that are now being widely applied to SCM in order to facilitate information pooling and sharing, as a result of which, there is obvious potential for improvements in operational performance. Such improvements include reductions in inventory levels and transaction costs, the shortening of order cycle times and increased operational efficiency (Hartley et al., 2004; Huang & Iravani, 2005; Klein, 2007; Barratt & Oke, 2007; Chen et al., 2007).

The e-auction mechanism is particularly useful in cases of uncertain sources of supply (involving, for example, agri-products) or uncertain customer demand (such as the demand for cut flowers). Furthermore, it is quite clear that the e-auction system can be successful, provided that the participants focus less on price competition and more on improving their operational and transactional activities, thereby reducing both time and costs, whilst also eliminating losses from product waste (Hartley et al., 2004). From all of the above, we now state our final proposition, as follows:

Proposition 4: *If IT, as an external condition, is introduced into a SCN, then (a) there will be an increase in operational efficiency and (b) a corresponding reduction in wastage losses.*

According to the four propositions developed above, we can conclude that the evolutionary forces of a SCN comprise of external conditions (involving, for example, IT systems) and internal factors (including changes in agents, decision rules and connectivity). Such interactive forces trigger the changes in the SCN, with the appropriate degree of fitness arising amongst agents to produce the aggregate outcomes. As illustrated in the conceptual framework for this study (Figure 2), this 'fitness' function represents the best performance objectives, such as growth, stability and efficiency.

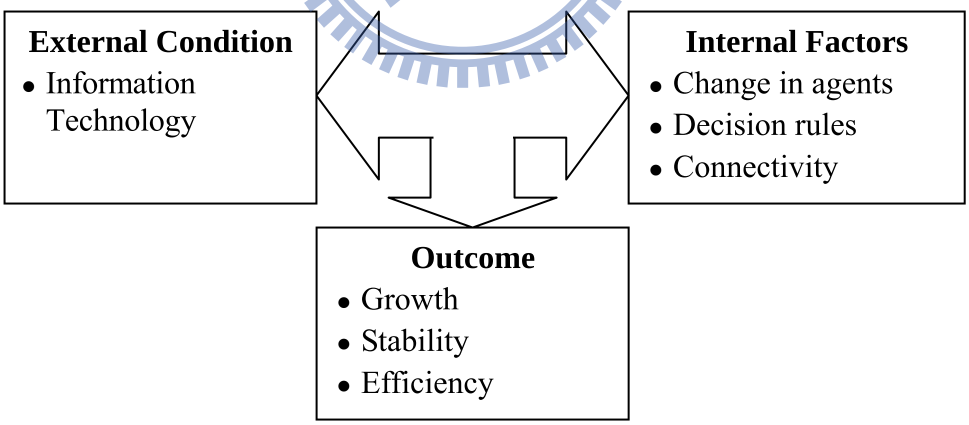


Figure 2. Conceptual framework of this study

This study contributes to SCM, from a perspective of CAS and IT, through the four propositions stated above based upon a review of the phenomena of supply chain evolution, as well as performance enhancements through the introduction of IT. Firstly, we use the real-world case study of the Taiwanese cut-flower industry to provide substantial evidence to demonstrate that the evolutionary forces comprise of external conditions and internal factors, with the outcome being the improvement of system performance as a result of such evolution.

Secondly, from the above review of potential improvements in supply chain performance through IT, we can conclude that there is a clear requirement for all agents within the chain to recognize the need to embrace the types of IT systems that are now being widely applied to facilitate information pooling and sharing, as a result of which, there will be clear potential for improvements in system performance, such as an increase in transaction quantity, a reduction in the volatility of price stability and visibility, and improved operational performance through a reduction in wastage losses (surplus).

Although all of the related issues examined above, such as the evolution of supply chains from a perspective of CAS and IT, already exist as separate areas of research in various industries, relatively little evidence has thus far been provided on these issues; this is particularly true with regard to the degree of fitness arising amongst agents to produce the aggregate outcomes. There is also relatively little evidence of any analysis of supply chain evolution in the real world. The conclusions and implications drawn from our results can therefore be further applied to SCM in general.

3.2 Methodology

The analytical processes undertaken in this study as the means of investigating the evolutionary phenomena, are based upon two distinct macro- and micro-study perspectives, with an illustration of the methods adopted to demonstrate the theoretical propositions of this study being provided in Figure 3.

We adopt a macro-study methodology to restructure the evolutionary phenomena of

Taiwan's cut-flower supply chains, dividing the overall evolutionary process into three distinct stages in order to observe those forces triggering supply chain evolution. The fitness of agents characterizing the evolutionary outcomes in the SCN is also investigated in this study, with our macro-study methodology including the analysis of a real-world case study aimed at testing Proposition 1.

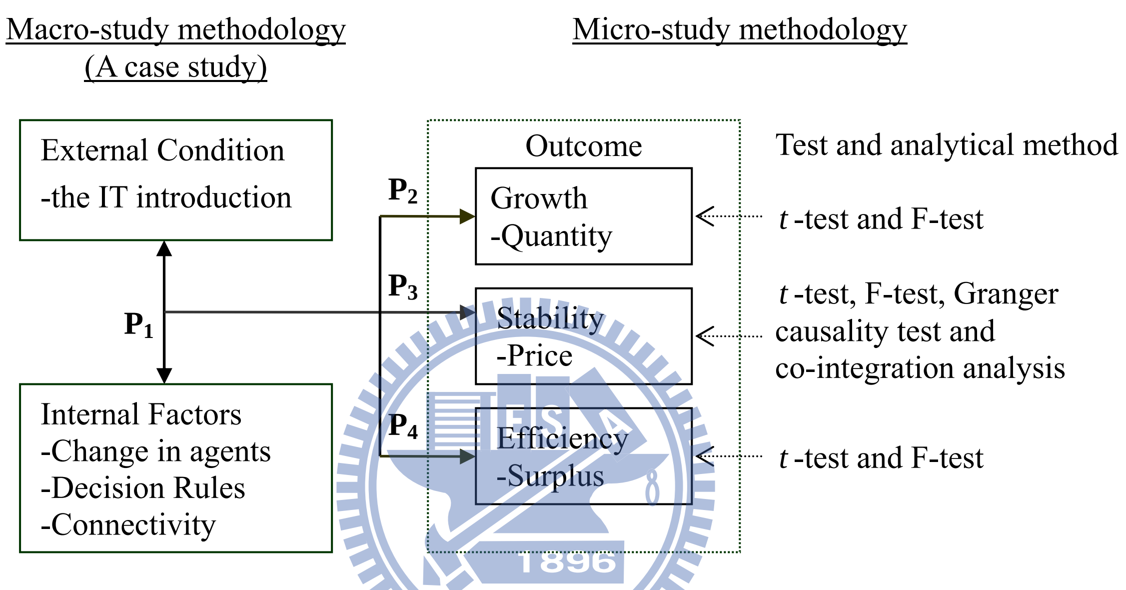


Figure 3. Description of propositions and adopting methods

We subsequently go on to adopt a micro-study methodology with the primary aims of verifying and providing further insights into the evolution of SCNs, and investigating the effectiveness of IT during the different evolutionary stages. The performance indicators for a SCN, comprising of transaction quantity, price and surplus, provide a useful means of assessing improvements in such performance; transaction quantity is defined as the average monthly auction quantity in each auction house, whilst price is defined as the average monthly (and daily) auction price in each auction house, and surplus is identified as any flowers which cannot be traded on the following day.

3.2.1 Macro-study Methodology

We adopt a case study approach for our macro-study perspective since this facilitates the identification of those forces driving the evolution of supply chains, as well as other factors with any influence on such evolution. The research methodology adopted for the examination of supply chain evolution in this study follows the inductive case study methodology of Mintzberg and McHugh (1985) based upon a longitudinal approach.

The evolution of a supply chain can be effectively analyzed through the reconstruction of the behavior of the system after each identifiable causal event; such historical reconstruction is regarded as being particularly feasible for the present study. Based upon the methodology of Mintzberg and McHugh (1985), we can determine that there are five major steps involved in such historical reconstruction (Figure 4): (i) collect primary data through in-depth interviews, in-house document sourcing and the auction house website; (ii) divide the evolutionary process into three distinct chronological stages; (iii) analyze any inferable patterns emerging during each of the three stages to determine the major changes in the SCN; (iv) identify important indicators based upon external conditions, internal factors and system fitness to describe the evolutionary process; (v) conceive a number of theoretical questions, such as which forces actually trigger SCN evolution, what patterns, behavior and connectivity subsequently emerge, and exactly where performance is improved, in order to interpret each evolutionary stage.

Case studies are generally recognized not only as being particularly valuable in exploratory research, but also as a good method of gaining a complete understanding of the observed patterns that may have occurred, and why they occurred. In principle, a historical reconstruction is both more feasible and more desirable; we therefore set out in this study to investigate the three evolutionary stages and the characteristics of each stage. These are identified and classified according to the primary data from the in-depth interviews undertaken with senior managers, as well as with the founder of the WISH system, and through in-house document sourcing.

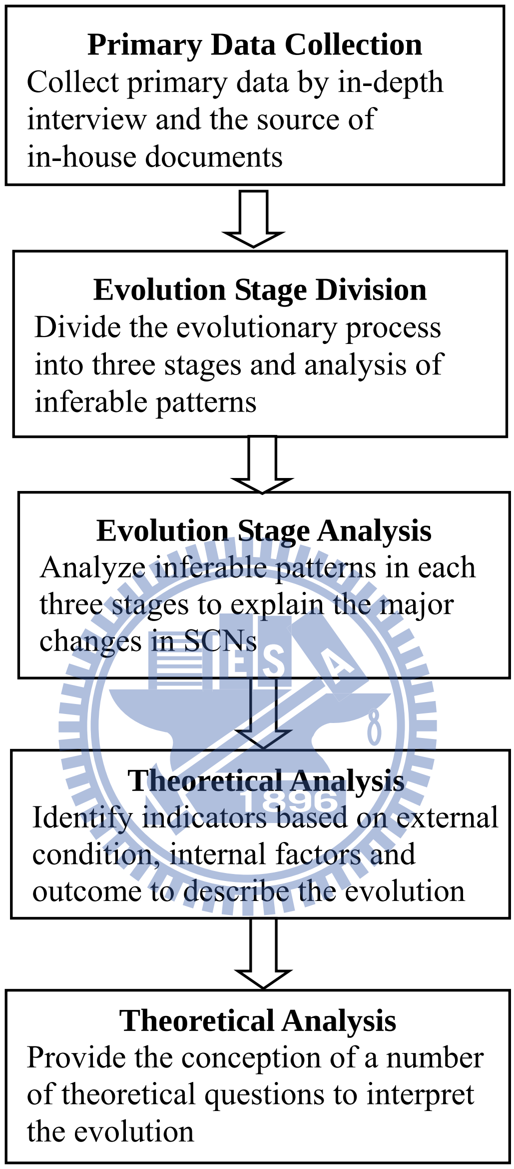


Figure 4. Flowchart of macro-study methodology

3.2.2 Micro-study Methodology

Specific tests and analytical methods are adopted in this study to examine whether IT has any significant effect on the evolution of supply chains by increasing the 'fitness' of agents. In order to clearly identify such evolution, which in turn further improves supply chain performance, time-series data are retrieved from both the WISH system and a collection of in-house documents.

3.2.2.1 Data collection

The transaction data for our micro-study perspective were subsequently divided into three phases for our longitudinal approach (Figure 5), with the indicators considered in this study being quantity, price and surplus. Some of these indicators were subsequently transformed into measurable variables, such as the transformation of price data into real terms (real prices), using a price index deflation method in order to deflate value added at the current rate. The price index adopted is the wholesale price index (WPI), with 2005 being used as the current period. The surplus indicator is transformed into a surplus ratio (equal to surplus divided by supply). Finally, a number of tests and analytical methods were adopted in order to compare the indicators (system performance) during the distinct stages, and to identify the evolutionary outcomes through IT.

We adopt a two-phase analysis for our empirical study of the evolution of supply chains so as to determine the major implications for SCM. The daily and monthly transaction data, covering the period from January 1998 to March 2010, are retrieved from the WISH system and then divided into two sub-periods. The earlier period, which runs from January 1998 to August 2003 (retailer-driven stage), is used to estimate the indicators in the different auction houses of TPAH, CHAH, TNAH and TCAH, including factors such as growth in transaction quantity, price stability and the efficiency of operations, whilst the later period, which runs from September 2003 to March 2010 (e-system driven stage), is adopted to examine the overall effectiveness of IT intervention.

3.2.2.2 Analytical methods

A number of tests and analytical methods are adopted in this study for the systematic analysis of the data collected from the WISH system, as shown in the following sub-sections; all of the analyses are performed using the EVIEWS statistical software package.

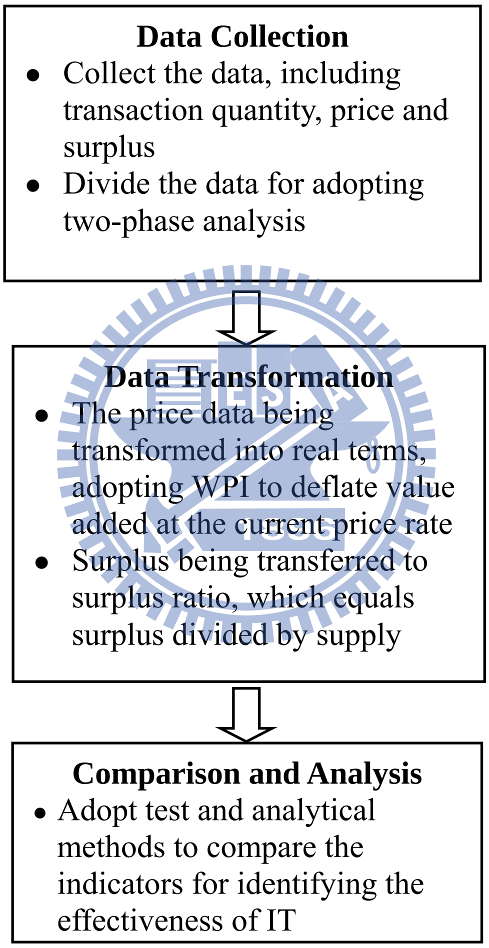


Figure 5. Flowchart of micro-study methodology

3.2.2.2.1 Mean and variance tests for the two independent populations

We adopt the *t*-test to compare the means of the two independent populations; this test assesses whether there are any statistically significant differences between the means of the two groups. The following assumptions should be met: (i) the two independent populations must follow normal distribution (adoption of the Jarque-Bera test); (ii) if the two populations do not follow normal distribution, then we must adopt the Wilcoxon signed-rank test; (iii) according to Student's original definition of the *t*-test, in any comparison between two populations, both should have the same variance.

If the sample sizes in the two groups are roughly equal, then Student's original *t*-test is highly robust to the presence of unequal variances; if the two sample sizes are unequal, or if the two distributions have the same variance, the *t* statistic for the assessment of whether there are differences in the means can be calculated as follows:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{S_{X_1X_2} \times \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \qquad (1)$$

where $S_{X_1X_2} = \sqrt{\frac{(n_1 - 1)S_{X_1}^2 + (n_2 - 1)S_{X_2}^2}{n_1 + n_2 - 2}}$ is the unbiased variance estimator; in other words, it is an estimator of the common standard deviation of the two samples; *n* in Equation (1) is the number of participants, (with a 1 indicating group 1, and a 2 indicating group 2); and $n_1 + n_2 - 2$ is the total sample size.

If the two samples are unequal and there are differences in the variances of the two populations, then Welch's *t*-test, used to determine whether there are differences in the population means, is calculated as follows:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{s_{\bar{X}_1 - \bar{X}_2}} \qquad (2)$$

where $S_{\bar{X}_1 - \bar{X}_2} = \sqrt{\frac{S_{X_1}^2}{n_1} + \frac{S_{X_2}^2}{n_2}}$ is the unbiased estimator of variance, but not pooled variance. The distribution of the test statistic is approximated as being an ordinary Student's *t* distribution, with the degree of freedom being calculated based upon the Welch-Satterthwaite equation (Satterthwaite, 1946; Welch, 1947).

A variety of tests can be used to compare the variances between two independent populations, including the *F*-test, Siegel-Tukey test, Levene's test, Bartlett's test or the Brown-Forsythe test; these tests assess whether there are any statistically significant differences in the variances between the two groups. One assumption which should be obeyed is that the two populations being compared should follow normal distribution.

3.2.2.2.2 Granger causality test

The Granger causality test (Granger, 1969), which has been widely used in economics ever since the 1960s, is an extremely effective statistical technique for determining whether one time series can help to forecast another. If a time series, *X*, is said to Granger-cause *Y*, this indicates that the past values of *X* containing certain information help to predict *Y*; that is, from a series of *F*-tests on the lagged values of *X*, these values provide statistically significant information on the future values of *Y*. Despite its name, Granger causality does not imply true causality, but actually indicates the relevance between *X* and *Y*.

3.2.2.2.3 Co-integration analysis

Co-integration is a concept for modeling the equilibrium of economic variables with long-run relationships. Ever since the seminal work of Engle and Granger (1987), there has been a continuous stream of interest in co-integration analyses of equilibrium relationships, using non-stationary economic variables.

A subsequent approach to the analysis of co-integration systems, undertaken by Johansen (1991), has also received much attention. Johansen suggested the use of the maximum likelihood method for the estimation of long-run equilibrium relationships or co-integrating vectors in order to derive likelihood ratio tests for co-integration within a Gaussian vector error correction model. The Johansen test is also adopted in the present study to perform co-integration analysis testing maximum eigenvalue and trace.

Our analysis comprises of four steps, the first of which involves an examination of the non-stationary of each variable using the augmented Dickey-Fuller test (1981), and then determining the order of integration with the individual variables. The second step involves determination of the lag order which is selected under certain criteria; the criteria method commonly adopted for such selection is the Schwarz information criterion. The third step involves the application of the Johansen test for cointegration amongst several time series; it should, however, be noted that this test does not require all of the variables to be in the same order of integration. The fourth step is the unit root test for identifying stationary within the residual terms. If all of the economic variables are found to be co-integrated, we can say that such variables have a long-run equilibrium relationship.

3.2.2.3 Data summary

As noted earlier, the important indicators considered in this study comprise of transaction quantity, price and surplus ratio. The definition of each indicator is presented in Table 1, with summary descriptions of all the data subsequently being provided in Tables 2, 3 and 4.

3.2.2.3.1 Quantity data

The means and variances of transaction quantity in the different auction houses are shown in Table 2. As the table shows, between January 1998 and August 2003 (the end of Stage 2), the transaction quantity in TPAH was higher than in CHAH, TNAH and TCAH; however, the volatility of transaction quantity was greater in TPAH than in any of the other auction houses. The average quantity in Stage 3 was also higher in TPAH than in any of the other auction houses, although, once again, the volatility of transaction quantity was higher in TPAH than in CHAH, TNAH, TCAH and KHAH.

Table 1. Definition of indicators

Indicators	**Definition**	**Unit**
Transaction quantity	Transaction quantity is average monthly auction quantity in each auction house	Million bundles
Transaction price	Price is characterized as average (monthly and daily) auction price in each auction house	Dollars
Surplus ratio	Surplus ratio equals surplus divided by supply	Percentage

Table 2. Summary descriptions of quantity in Stages 2 and 3 (unit: million bundles)

Stage2	**TPAH**	**CHAH**	**TNAH**	**TCAH**	**KHCH**	**TOTAL**
Mean	2.6228	1.7537	1.1546	0.6347	n/a	6.1564
	(0.4315)	(0.2465)	(0.2115)	(0.1031)	n/a	(0.9416)
Jarque-Bera	4.91	5.53	3.29	4.92	n/a	5.50
P-value	0.09	0.06	0.19	0.09	n/a	0.06
Stage3						
Mean	2.4910	1.0755	1.0480	0.5914	0.9210	6.1268
	(0.6551)	(0.2998)	(0.3415)	(0.1489)	(0.2936)	(1.5485)
Jarque-Bera	4.90	5.95	5.88	5.75	6.42	5.46
P-value	0.09	0.05	0.05	0.05	0.05	0.06

Note: ‡: p<0.01 and †: p<0.05, standard deviation listed in parenthesis, observations are 68 and 79 in Stages 2 and 3, respectively, and the Jarque–Bera test is a goodness-of-fit measure of departure from normality.

3.2.2.3.2 Price data

Between January 1998 and August 2003, the monthly average price in TPAH was higher than in CHAH, TNAH and TCAH, whilst the price volatility was also greater in TPAH than in CHAH, TNAH and TCAH. Between September 2003 and March 2010, the average price in TPAH was once again higher than in all of the other auction houses; however, price volatility was found to be greater in both TPAH and KHAH as compared to CHAH, TNAH and TCAH (Table 3).

Table 3. Summary descriptions of price in Stages 2 and 3 (unit: dollars)

Stage2	**TPAH**	**CHAH**	**TNAH**	**TCAH**	**KHCH**	**TOTAL**
Mean	58.16	51.93	46.94	44.68	n/a	52.77
	(9.16)	(7.54)	(6.72)	(6.86)	n/a	(8.00)
Jarque-Bera	5.49	0.05	0.33	5.06	n/a	2.08
P-value	0.06	0.98	0.85	0.07	n/a	0.35
Stage3						
Mean	54.88	47.97	44.92	40.99	52.13	50.02
	(9.47)	(7.96)	(7.27)	(6.84)	(9.41)	(8.33)
Jarque-Bera	5.89	0.86	4.37	5.16	0.56	4.02
P-value	0.05	0.65	0.11	0.07	0.75	0.13

Note: ‡: $p<0.01$ and †: $p<0.05$, standard deviation listed in parenthesis, and observations are 68 and 79 in Stages 2 and 3, respectively.

Table 4. Summary descriptions of surplus ratio in Stages 2 and 3

Stage2	**TPAH**	**CHAH**	**TNAH**	**TCAH**	**KHCH**	**TOTAL**
Mean	4.04%	5.26%	6.01%	6.50%	n/a	5.02%
	(0.0174)	(0.0219)	(0.0242)	(0.0255)	n/a	(0.0202)
Jarque-Bera	4.34	5.36	3.15	3.79	n/a	4.03
P-value	0.11	0.07	0.21	0.15	n/a	0.12
Stage3						
Mean	2.70%	3.77%	4.03%	5.08%	4.50%	3.60%
	(0.0155)	(0.0197)	(0.0232)	(0.0221)	(0.0280)	(0.0189)
Jarque-Bera	3.85	5.16	4.82	3.96	5.92	4.95
P-value	0.15	0.07	0.10	0.14	0.05	0.10

Note: Surplus ratio equals surplus divided by supply, ‡: $p<0.01$ and †: $p<0.05$, standard deviation listed in parenthesis and observations are 68 and 79 in Stages 2 and 3, respectively.

3.2.2.3.3 Surplus ratio data

The means and variances of the surplus ratio in the different auction houses are shown in Table 4, which shows that between January 1998 and August 2003, the average surplus ratios were higher in both TNAH and TCAH than in CHAH and TPAH; however, the volatility of the surplus ratio was found to be greater in TNAH, TCAH and CHAH than in TPAH. In Stage 3, the average surplus ratio was higher in TCAH than in all of the other auction houses; however, surplus ratio volatility was found to be greater in KHAH, TNAH and TCAH than in either TPAH or CHAH.

4. RESULTS AND DISCUSSION

4.1 Taiwan's Cut-flower Supply Chains and the WISH System

This chapter reports the results on the evolution of Taiwan's cut-flower supply chains from a macro-study perspective. Major changes are found to have taken place in the cut-flower industry over the past two decades, with a discernible shift in certain supply chains, from traditional adversarial competition based upon individual firms, towards inter-firm coordination. In order to facilitate our examination of these changes, the overall evolutionary process is divided into three distinct stages.

4.1.1 Supply Chain Evolution in Taiwan's Cut-flower Industry

Our primary concern in this study is the evolutionary process of supply chains, with particular focus being placed upon the external conditions and internal factors supporting the development of the cut-flower industry during the three different evolutionary stages (Figure 6).

The three distinct stages of the evolutionary process comprise of the supplier-driven, retailer-driven and e-system-driven stages. The essential elements of the process of SCM throughout each of these three evolutionary stages are described in the following sub-sections.

4.1.1.1 Supplier-driven stage (pre-1988)

During this introductory stage (up to 1988), the vast majority of all production and sales was driven by individual growers providing scarce and somewhat unreliable sources of supply; thus, productivity remained quite low. According to available statistics, prior to

1970, the planted area of cut flowers in Taiwan amounted to 234 hectares, with market volume of NT$53 million (deflated by WPI, the real volume was NT$159 million).

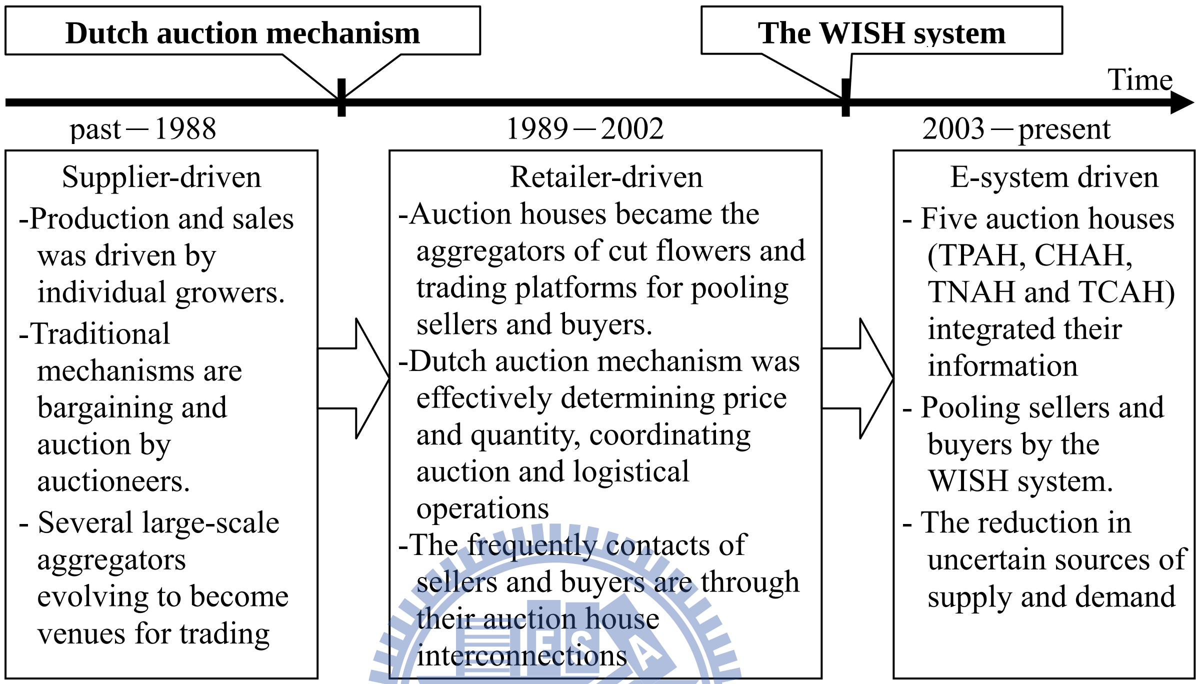


Figure 6. The evolutionary process of SCNs in Taiwan's cut-flower industry

During this stage, traditional mechanisms, such as bargaining and open-auction trading by auctioneers, were invariably applied to the negotiation of all cut-flower transactions, with such transactions being negotiated separately in different SCNs based upon single spot transactions. As a result, several large-scale aggregators evolved to become the generally accepted venues for trading. The emergence of erratic SCNs was therefore dependent upon the choices of producers aimed at creating probabilistic traders.

During this stage, competition was much more prevalent than cooperation, both within the same SCN and across various SCNs, with all members operating independently, and very little communication or coordination taking place. Based upon a comparison with other industries, the provision of cut flowers was further constrained by specific product features such as limitations due to weather conditions, discontinuous supply, demand volatility, greater surpluses and higher transaction costs. In other words, all of these factors tended to hinder the establishment and maintenance of relationships between members. As a result of all of these challenges, coordination proved to be extremely difficult to achieve.

The e-auction mechanism, which emerged in 1988, heralded the beginning of the shift from supplier-driven SCNs towards a retailer-driven system, with a discernible shift in market power from suppliers to customers. As noted above, the fragmented exchange of products within the cut-flower industry had led to certain challenges during the supplier-driven stage; as a result of better demand management, these were set to be reduced in the retailer-driven stage.

4.1.1.2 Retailer-driven stage (1989-2002)

During this second stage, the introduction of IT forced the establishment of the e-auction clock system, which follows a principle of price reduction based upon the Dutch auction system. This auction mechanism was capable of effectively determining price and quantity setting, coordinating production processes, flower categories and logistical operations, and forecasting the actions of suppliers and retailers in the entire auction-house force within the same SCN. Auction houses became not only the aggregators of cut flowers, but also trading platforms for growers and retailers. The operation of the auction system is illustrated in Figure 7, which shows that for each day, with the exception of those days when the auction houses announced they would be closed, the auction price and volume were automatically generated by the WISH system.

Four e-auction houses, designed specifically for retailers, were established between 1989 and 1995; TPAH had already been founded in March 1988 and subsequently achieved a growth rate of 65.74 percent in total transaction quantity of flowers between 1989 and

1990 (Figure 8). CHAH was set up in April 1994, with TNAH also being established in the same year. The total transaction quantity throughout the auction lines saw a further significant increase of 30.44 percent between 1993 and 1994, with the main contribution to this market growth having been made by CHAH. The total transaction volume continued to increase rapidly between 1994 and 1995 (by about 66.11 percent), with CHAH and TNAH being the major contributors. The setting up of TCAH in January 1995 further contributed to market growth.

With the continuing evolution of the cut-flower industry, the total transaction volume throughout the auction lines had grown by approximately 10.17 percent between 1995 and 1996, with the main contributions to growth having come from TPAH, CHAH, TNAH and TCAH. Before 1990, the planted area for cut flowers had expanded to 1,200 hectares, with market volume being NT$407 million (real volume of NT$490 million); however, by 1999, the planted had grown to 4,789 hectares, with market volume rising to NT$3,372 million (real volume of NT$3,951 million). From 1996 onwards, TPAH, CHAH, TNAH and TCAH were together accounting for the total market share of the cut-flower industry in Taiwan, with all of the auction houses also accounting for the majority of all retail sales.

It should be noted that during this period, the soaring growth in cut flowers was mainly due to the adoption of the e-auction mechanism; this stage therefore represents a very important period in the overall evolution of the cut-flower industry in Taiwan.. Based upon the e-auction platform, frequent contacts between producers and retailers through their auction house interconnections gave rise to the establishment of inter-firm relationships through contractual arrangements. Under such contractual arrangements, agents in the auction houses were able to engage in reverse integration with producers, as well as in forward integration with retailers, based upon fixed auction lines. Thus, the auction houses had succeeded in overtaking the suppliers to emerge as the more powerful players, in terms of overall procurement decision making based upon customer demand, and the effective management of suppliers and retailers through the imposition of economic sanctions (such as penalties or termination of supply).

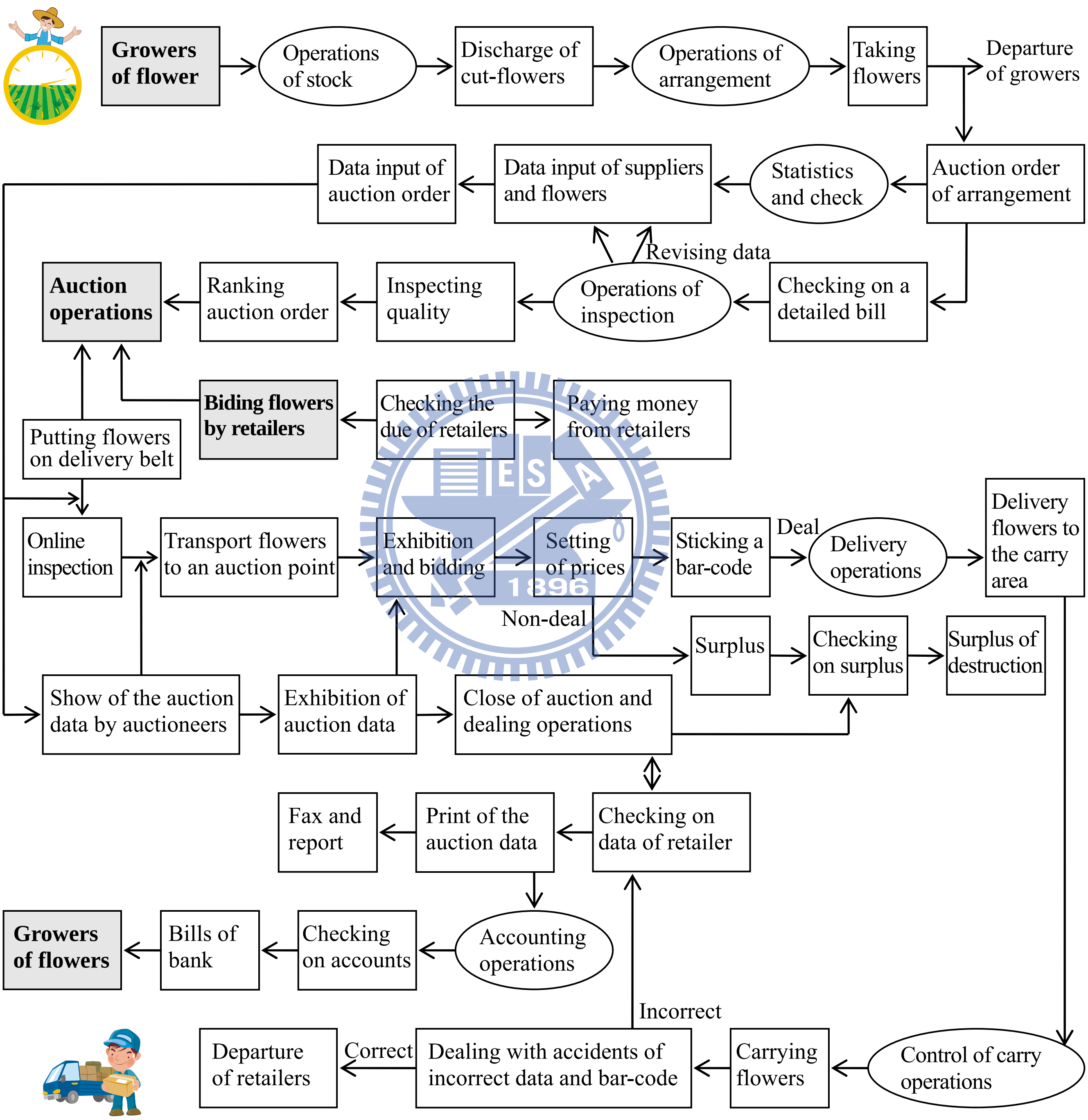


Figure 7. The scenario of auction operations with cut flowers

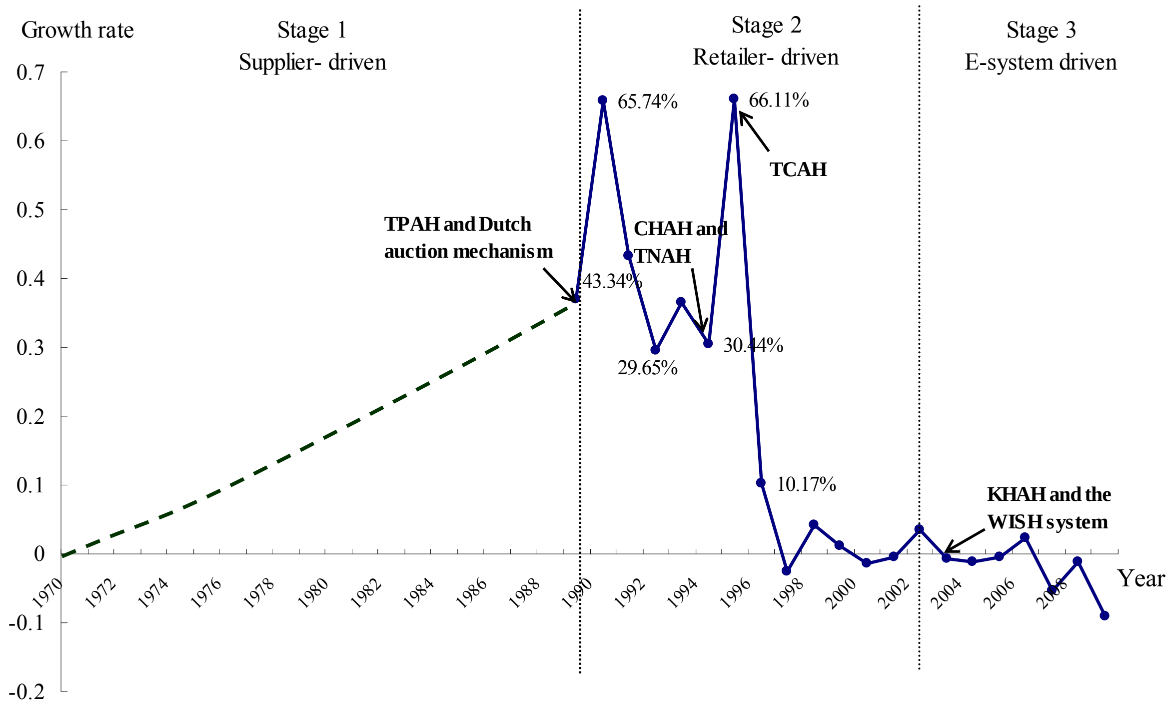


Figure 8. Growth rate of total transactional quantity in Taiwan's cut-flower industry

During this stage, a response to changes in consumption attitudes – such as preferences for higher quality and variety in cut flowers – was evidenced in June 1992 through the introduction of common standards of quality certification and packing to be applied to all suppliers, in order to increase the efficiency of auction operations and meet the quality requirements of consumers. As a result, retailers invariably purchased their flowers in the neighboring auction houses. Furthermore, the rise in coordinative behavior amongst the various agents could also offer substantial benefits, such as improvements in operational efficiency and a reduction in both transaction costs and cut flower surpluses within the SCNs. Indeed, during this stage, examples of vertical cooperation were already an established feature of the supply chain evolution within the cut-flower industry.

4.1.1.3 E-system-driven stage (2003-present)

In this final and ongoing evolutionary stage, the structure of the cut-flower industry was becoming far more sophisticated and coordinated. Horizontal coordination across supply chains was forced upon the network though information sharing in the WISH system which had evolved during this stage to become an essential SCM mechanism and characteristic.

The adoption of the WISH system has led to much more comprehensive information sharing, thereby alleviating much of the uncertainty in both supply and demand. As a result of the newfound levels of coordination, formerly dispersed supply chain parties are now integrated into a single virtual network with all goals and operational activities being effectively aligned. Agents within the auction houses are therefore able to coordinate the operations of demand management and transshipment systems and can forge ahead with the production of specific flower species from a few, large-scale, trusted producers, aimed at meeting the diverse demands of retailers. As IT systems continue to become more advanced, the e-supply chain has the capability of leveraging the benefits arising from visibility across SCNs, thereby leading to performance improvements, appropriate responses to changing demand and increasingly developed retailer services.

KHAH was founded in September 2003 in an attempt to satisfy the requirements of local retailers and to advance the level of services provided to them; as a result, many of the nearby cut flower producers and retailers subsequently began trading in this auction house. Following the introduction of KHAH, the natural outcome was the redistribution of market share within Taiwan's cut-flower supply chains. According to transactional data statistics obtained from the WISH system, in 2004, the total market volume was NT$3,431 million (real volume of NT$3,647 million), with continuing growth to NT$3,838 million having been recorded in 2005 (real volume rising to NT$4,055 million).

From a holistic standpoint, the development of these five auction houses in the Taiwanese cut-flower industry meant that they were now covering virtually all retail sales, with the traders in these auction houses being widely geographically dispersed throughout the island. By observing the changing circumstances within the three defining stages described above, we can further identify important indicators arising from the interaction between external conditions and internal factors to describe the evolution of the supply chains in the cut-flower industry in Taiwan. The patterns of behavior of members in each evolutionary stage are described to further identify the forces triggering the evolution of the supply chain, the rule changes within the supply chains, and performance improvements within each of the distinct evolutionary stages.

As described in the foregoing sections, agency-based coordination has continued to develop amongst all of the parties involved, in both the same auction lines, as well as across the various auction lines. It is, therefore, quite clear that coordination through IT represents an essential strategic element of SCM, particularly with regard to the scenario examined in the present study.

4.1.2 Market Share in Taiwan's Cut-flower Supply Chains

The market share indicates the proportion of the total available market accounted for by each of the auction houses. The statistics on market share and growth rate for each of the auction houses are respectively presented in Tables 5 and 6. The ranking of the auction houses between January 1998 and August 2003, by market share in descending order, was TPAH, CHAH, TNAH and TCAH (Table 5), whilst the market share ranking in terms of the growth rate was TNAH, TCAH, CHAH and TPAH (Table 6). During this period, TPAH represented the largest cut-flower auction house, albeit with a negative growth rate. Conversely, whilst TCAH was the smallest cut-flower SCN, it had the most rapid growth rate.

Table 5. Descriptive statistics of market share and growth rate in Stage 2

	Market share				**Growth rate**			
	TPAH	CHAH	TNAH	TCAH	TPAH	CHAH	TNAH	TCAH
Mean	42.45%	28.52%	18.69%	10.33%	-0.0003	0.0008	0.0066	0.0064
Max	46.46%	32.50%	22.37%	11.82%	0.1412	0.0844	0.7331	0.1865
Min	38.87%	26.32%	10.83%	7.98%	-0.1300	-0.0872	-0.4033	-0.1300
Std. Dev.	1.54%	1.25%	1.56%	0.80%	0.0429	0.0393	0.1178	0.0672

Between September 2003 and March 2010, the market share ranking had changed to TPAH, CHAH, TNAH, KHAH and TCAH (Table 5), whilst the growth rate ranking had changed to KHAH, TNAH, TCAH, TPAH and CHAH (Table 6). In Stage 3, TPAH remained the largest auction house, whilst TCAH was the smallest.

Table 6. Descriptive statistics of market share and growth rate in Stage 2

	Market share					**Growth rate**				
	TPAH	CHAH	TNAH	TCAH	KHAH	TPAH	CHAH	TNAH	TCAH	KHAH
Mean	42.45%	17.62%	17.09%	9.68%	15.03%	0.0023	-0.0002	0.0100	0.0042	0.0617
Maximum	44.48%	24.83%	30.05%	11.15%	25.46%	0.1156	0.4369	0.8297	0.1711	4.2387
Minimum	36.55%	11.99%	12.65%	7.82%	4.86%	-0.1621	-0.2968	-0.3831	-0.2393	-0.6632
Std. Dev.	1.49%	2.30%	3.08%	0.71%	2.97%	0.0494	0.0942	0.1337	0.0739	0.5431

4.1.3 The WISH System

The WISH system, which was established in 2002, formally began operations, involving the sharing of raw transaction data, in September 2003; it comprises data sourcing, data transformation, data warehouse, data mining, hyper cube and business model (Liang, 2003). The software used in this system includes Impromptu, PowerPlay Web Server, and Visualizer from the Cognos in Canada. Such Impromptu software is useful in establishing catalog to set up a series reports; the finished reports can further create the file of

Impromptu Query Definition (*.IQD) to make up hyper cube (Multi-dimension Cube). PowerPlay Web Server is useful in proceeding to the multiple-dimension analyses, with creating 12 dimensions and 24 performance measures. The software of Visualizer can be useful in showing visualization cut-flower data in the WISH system.

This WISH system comprises of several data marts and a data warehouse engaging in the automatic collection and transmission of daily transaction data from auction clocks in each of the auction houses via the Internet (refer to Figure 9). The system is also equipped with advanced data analysis tools, such as On-Line Analytical Processing (OLAP), On-Line Analytical Mining (OLAM) and Business Intelligence (BI), enabling it to efficiently integrate and analyze all daily transaction data. Such BI aims to support business decision-making, thus it is also called a decision support system (DSS).

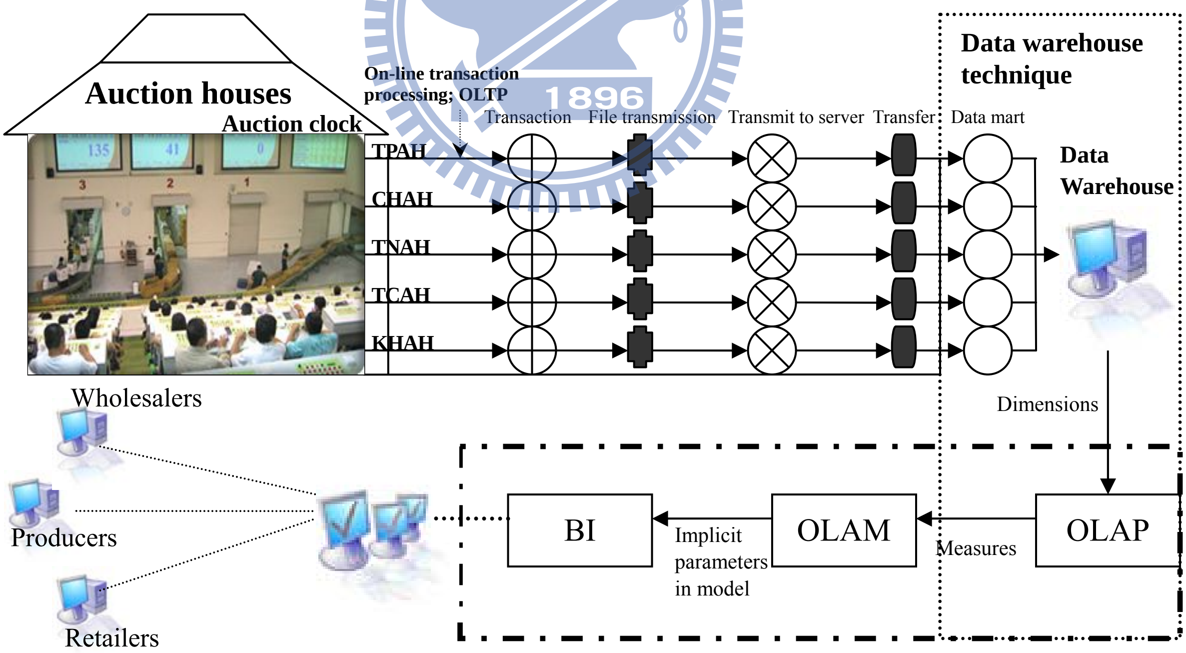


Figure 9. The information flow of the WISH system

There are a total of 12 dimensions in this system, including date, week, type of supplier, location of supplier, location of retailer, flower assortment, flower grade, auction line, container, auction house, celebration (e.g. Valentine's Day and so on) and lunar calendar. In addition to these dimensions, a total of 24 performance measures are recorded within the system, such as auction quantity, auction price, auction volume, total transaction quantity, total transaction price, total transaction volume, and supplies, etc.

4.2 Supply Chain Network Organization

The configuration of Taiwan's entire cut-flower SCN is illustrated in Figure 10, which describes how the agents within the SCN engage in their auction operations, logistics and communications. In the initial stage, our network form is depicted as a large-scale aggregator, representing the center of a stable network formation driven by the choices of cut-flower growers to create their probabilistic traders. Thereafter, such large-scale aggregators evolved to become auction houses. Although the growers are the cut-flower suppliers (farmers, agribusiness or associations), they do not supply other products, such as young plants, seeds, manure, chemical products, wood or other raw materials. The cut flower buyers represent the retailers, including wholesalers, distributors and flower shops.

The organization of the network during the second stage was characterized by agents cooperating through the Dutch auction mechanism, essentially reliant upon the contacts between growers and retailers through their auction house interconnections, which gave rise to the establishment of contractual relationships. In the final stage, the network form is characterized as horizontal coordination across auction houses through the adoption of the WISH system leading to much greater information sharing.

On the one hand, the SCN examined in this study has the characteristics of a CAS, within which the interactive agents successfully adapted to environmental changes by altering their noble decisions, with schemata, to ultimately achieve the primary aim of integrating their operational and transactional activities, and thereby achieving better performance. On the other hand, the SCN highlights the sharing of valuable information amongst the various agents between the second and final stages.

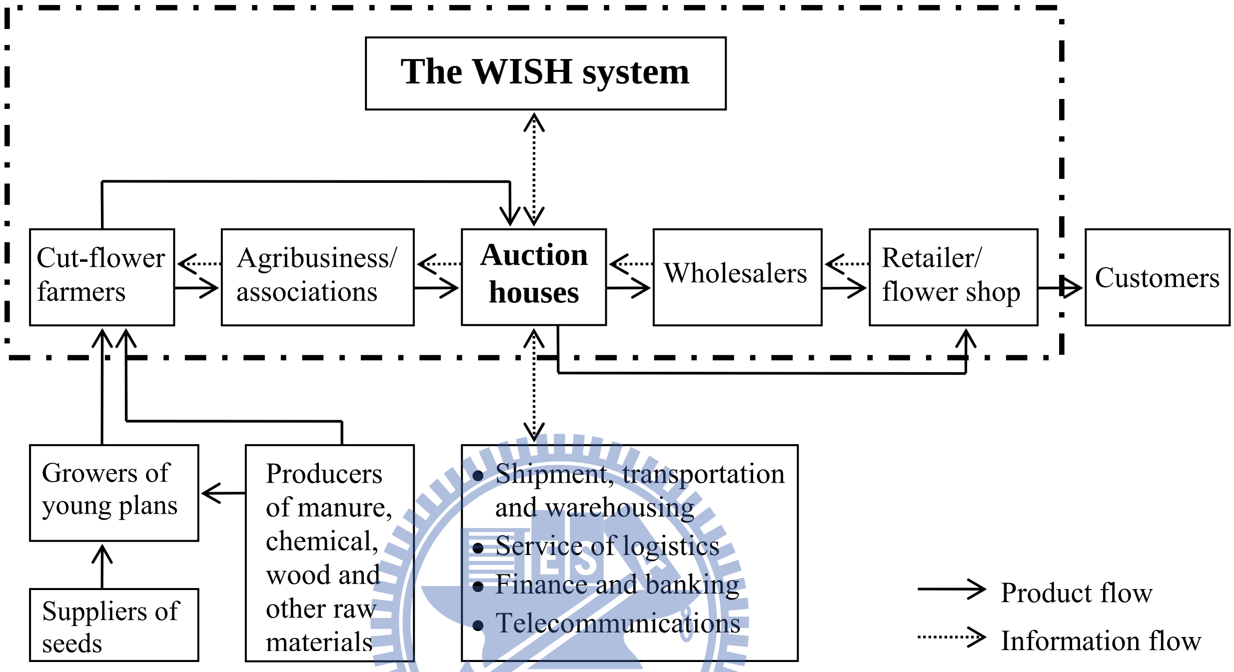


Figure 10. The configuration of cut-flower supply chains

4.3 Evidence on the Propositions of this Study

Our investigation of the evolution of a SCN within a dynamic environment from a macro-study perspective illustrates how this SCN has evolved in three distinct stages, during which the changes in the behavior of agents, decision rules and connectivity have driven the evolution of the supply chain, with the successful evolution of the SCN being verified in this study in the form of performance improvements.

4.3.1 Evolutionary Forces

The first of our propositions is supported by the analytical results obtained between both the introductory and second stages, and the second and final stages. The external conditions imposed upon the system between Stages 1 and 2 (the introduction of IT) forced the establishment of the Dutch auction mechanism, thereby increasing auctioning efficiency and improving auction operations (Figure 11).

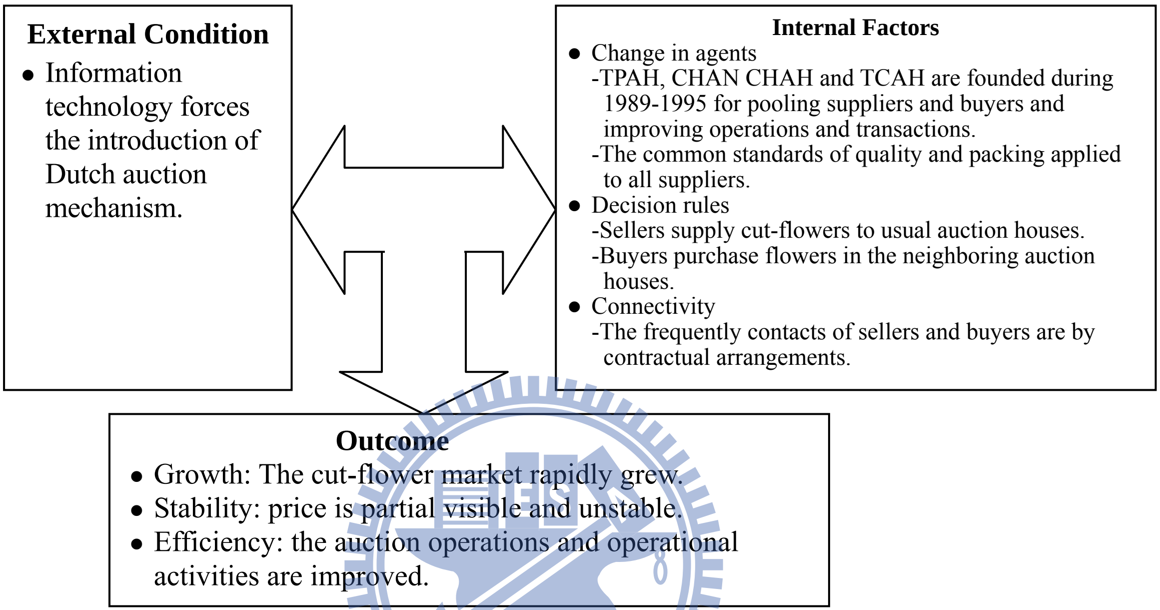


Figure 11. The evolutionary forces between Stage 1 and 2

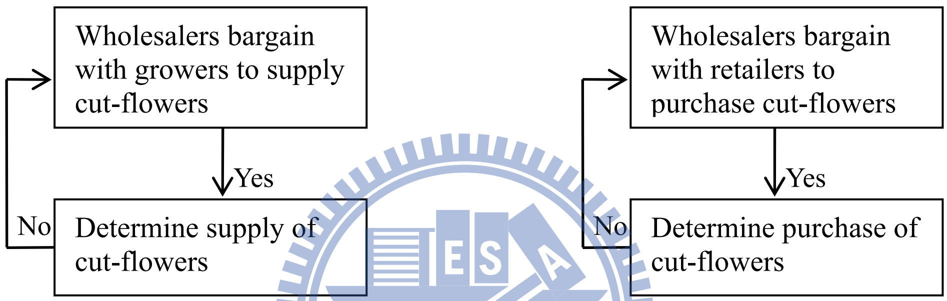
Cut-flower transactions through bargaining had traditionally been controlled by large wholesalers as the intermediaries between sellers and buyers; however, since they gained most of the profits from producers and retailers, cut-flower productivity and sales remained quite low. Open-auction trading by auctioneers was also recognized as an inefficient mechanism essentially because of the lower capacity of such auction operations. Based upon a comparison with other industries, certain problems existed in the cut-flower industry, such as low production volume, uncertainty of supply and demand, higher transaction costs, operational inefficiency and price invisibility. In other words, all of these factors tended to hinder both the growth and stability of the cut-flower market. As a result of all of these challenges, coordination was difficult to achieve.

The problems throughout the cut-flower industry during the supplier-driven stage, due to the fragmented exchange of flowers, were set to be reduced in the retailer-driven stage as a result of better demand management through the adoption of the Dutch auction mechanism. Agents had proven sensitive to the changes in the external environment and had reacted accordingly. TPAH was founded in March 1988, in an attempt to satisfy the requirements of retailers; as a result, producers and retailers subsequently began trading in cut flowers in TPAH. The agents learned from their interactions and adaptation to the introduction of the Dutch auction mechanism and attempted to increase their degree of 'fitness' leading to reductions in their transaction costs and increased operational performance. The best performance reports were increases in market volume and improvements in auctioning activities, which are discussed further below, whilst the common schema that were ultimately possessed by agents led to reduced transaction costs and increased operational efficiency.

During the period from 1992 to 1995, a series of changes took place within Taiwan's cut-flower supply chains aimed at improving auctioning operations and consequently increasing efficiency. This is evidenced in the common standards of quality certification and packaging that were to be applied to all suppliers within TPAH in June 1992. Disjointed entities were brought together to form new auction houses, such as CHAH, which was set up in April 1994, with TNAH also being established in the same year. TCAH was subsequently founded in January 1995.

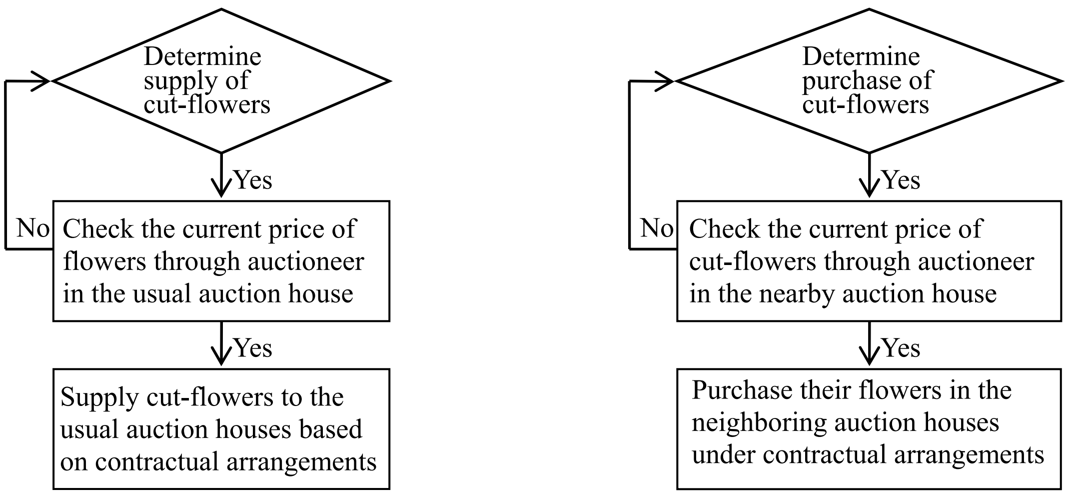
Thereafter, the standards of quality and packaging adopted in TPAH were soon mirrored in CHAH, TNAH and TCAH. The evolution of these auction houses had brought together most of the producers and retailers in the second stage, with their combined force virtually accounting for the entire market share. Of particular note is the fact that during this second stage there was a discernible shift in the driving force within the SCNs from producers to consumers.

The decision rules of the agents were also changed from the first stage to the second stage (refer to Figure 12 and 13), with suppliers evolving to provide the usual auction houses with their cut flowers, and retailers purchasing their flowers in the neighboring auction houses. Frequent contacts were developed during this period between sellers and buyers through their auction house interconnections based upon contractual arrangements.



a. Decision rule of suppliers **b.** Decision rule of retailers

Figure 12. Flowchart of decision rule of suppliers and retailers in Stage 1



a. Decision rule of suppliers **b.** Decision rule of retailers

Figure 13. Flowchart of decision rule of suppliers and retailers in Stage 2

As regards the evolutionary process in Taiwan's cut-flower industry between Stages 2 and 3, five auction houses (TPAH, CHAH, TNAH, TCAH and KHAH) were planning to integrate their information systems in order to resolve specific problems that existed within the cut-flower industry, such as uncertainty of supply and demand, and greater surpluses (Figure 14). Information sharing across SCNs was supported by the WISH system, thereby alleviating much of the uncertainty in both supply and demand and subsequently reducing surpluses in all of the auction houses. The agents in the auction houses were therefore able to coordinate the operations of demand management and transshipment systems across the various SCNs.

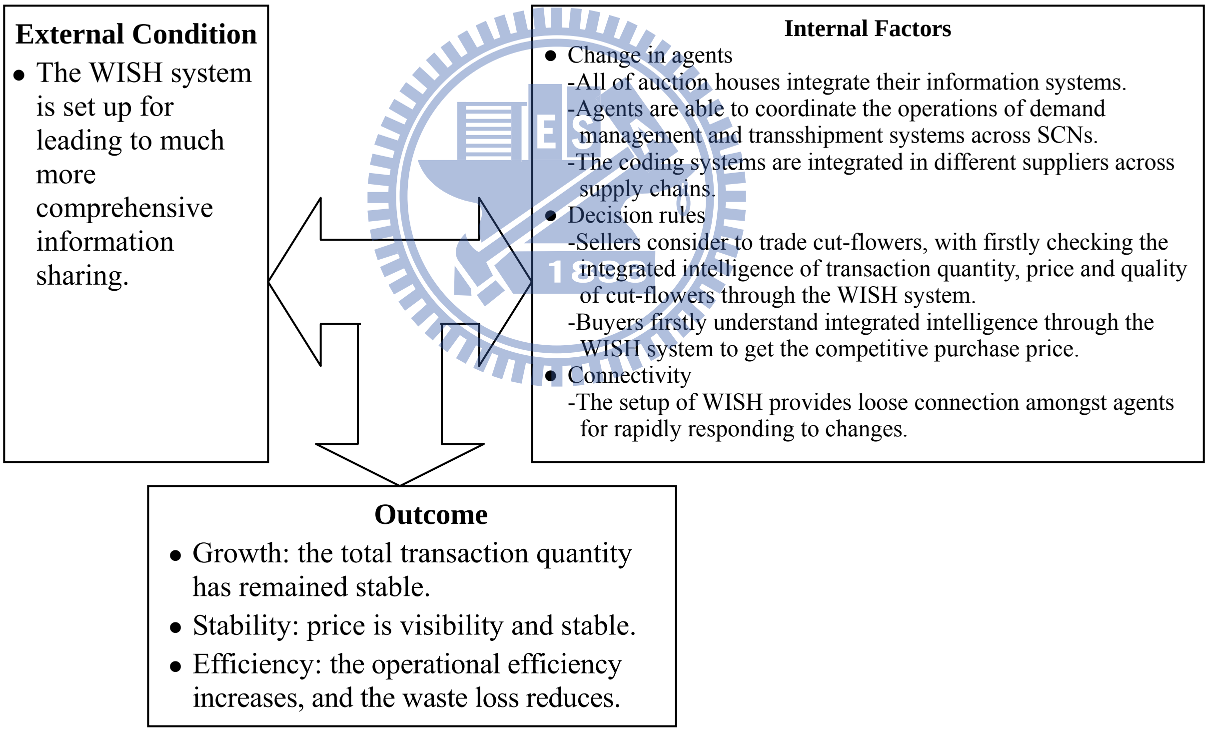
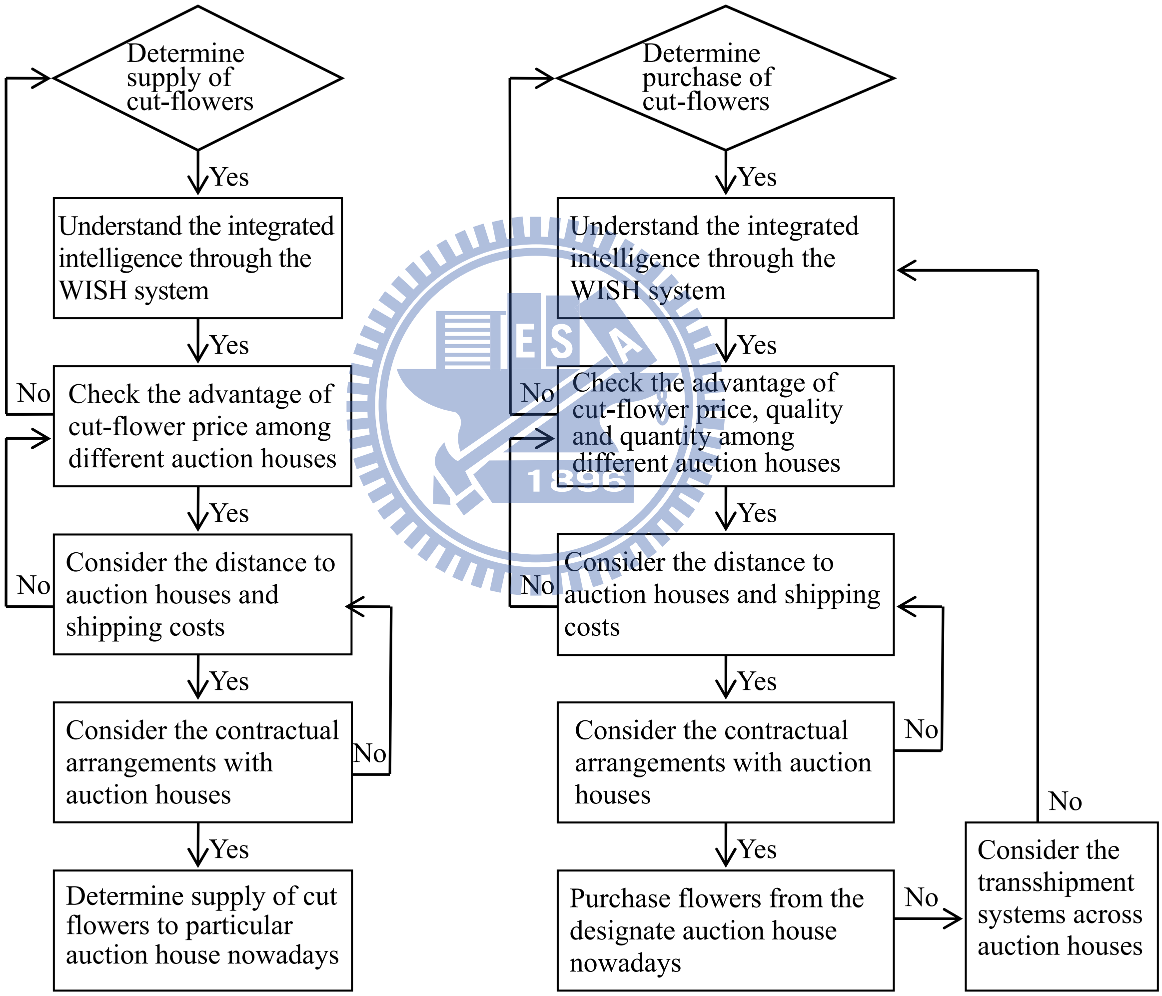


Figure14. The evolutionary forces between Stages 2 and 3

The decision rules of the agents have been further changed in Stage 3; before suppliers can provide their cut-flowers to the auction houses, they must first of all check the integrated intelligence on transaction quantity, price and quality (Figure 15). Similarly, retailers must consult the integrated intelligence on cut-flower purchases through the WISH system and then consider shipping costs, contractual arrangements and the distance to the auction houses, in order to select the appropriate auction house, thereby gaining a price advantage. Clearly, the loose connections amongst agents through the WISH platform have provided rapid responses to changes in this final stage.



a. Decision rule of suppliers   **b.** Decision rule of retailers

Figure 15. Flowchart of decision rule of suppliers and retailers in Stage 3

As IT systems have continued to become ever more advanced, so Taiwan's cut-flower supply chain has been developed to a level where it now has the capability of leveraging the benefits from visibility across different SCNs, thereby leading to improved performance, appropriate responses to changing demand and increasingly developed retailer services. Furthermore, an issue of considerable importance is the successful achievement of the aim of reducing wastage losses; this is attributable to the effective reduction in surplus cut flowers.

Proposition 1 in this study is supported by much of the evidence noted above, with the evolutionary forces of Taiwan's SCNs being found to comprise of external conditions and internal factors, and the process of evolution being regarded as a repetitive sequence of these forces during three distinct stages. Such evolution can only be successful if it brings about an increase in the degree of fitness amongst the agents. A summary of the evidence on increasing 'fitness', characterized by performance improvements, is provided in the following sub-section.

4.3.2 Outcomes

As noted above, the evolution of SCNs can only be successful if it brings about an increase in the degree of fitness amongst the various agents. This sub-section provides evidence on improvements in system performance, including growth in transaction quantity, price stability and operational efficiency.

4.3.2.1 Growth

Cut-flower production had remained quite low in the introductory stage; indeed, prior to 1970, the real transaction quantity was only 4,526,700 bundles (Figure 16). However, the total quantity of cut-flowers rapidly increased in Stage 2 as a result of the introduction of the Dutch auction mechanism. Having been founded in March 1988, TPAH subsequently achieved an annual growth rate of 43.80 percent in total transaction quantity of cut flowers between 1989 and 1994. In 1989, the real transaction quantity had been approximately 7,172,725 bundles; however, by 1994, the figure had risen exponentially, to 39,324,670 bundles. CHAH and TNAH were set up in April 1994, with total transaction quantity seeing further significant increases of 30.44 percent between 1993 and 1994, and 66.11 percent between 1994 and 1995. The setting up of TCAH in January 1995 made a further contribution of approximately 10.17 percent to market growth over the subsequent year (with total quantity rising to 71,963,530 bundles).

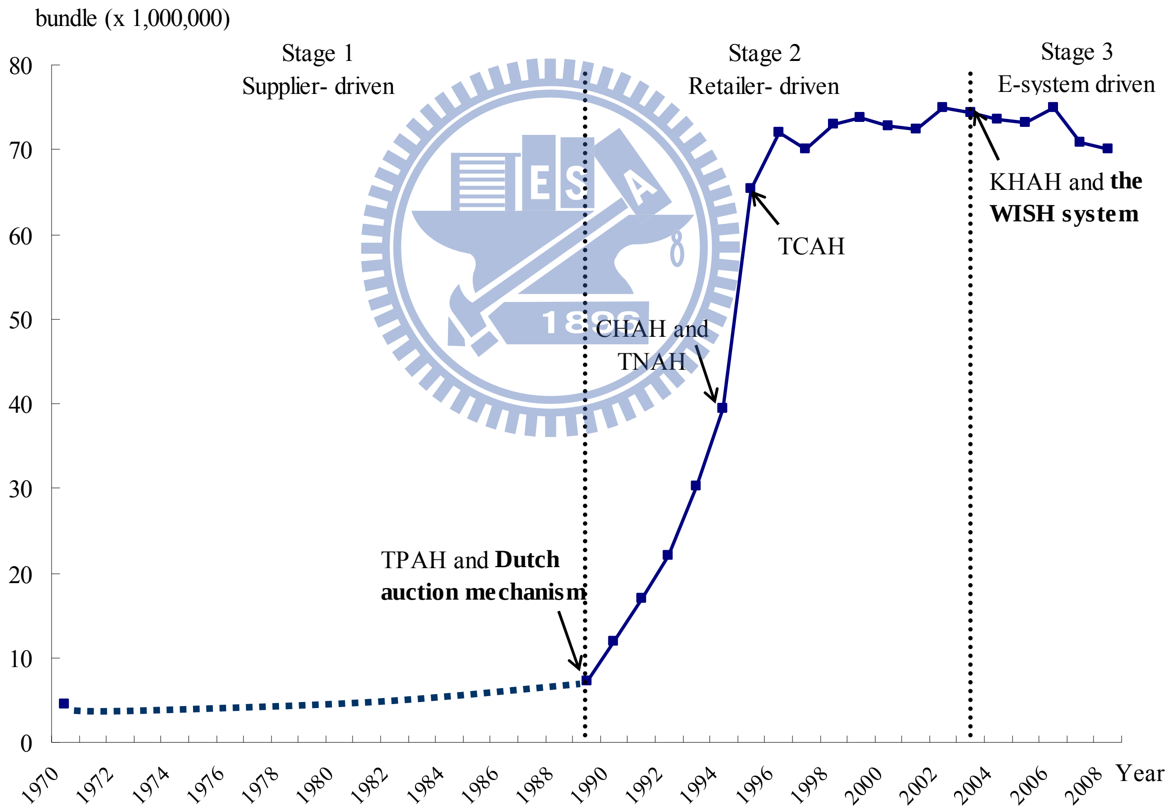


Figure 16. The Trend of transactional quantity in Taiwan's cut-flower industry

There was, however, no significant increase in total transaction quantity in the period of September 2003 and March 2010 (Stage 3) when KHAH and the WISH system were set up. Furthermore, significant reductions in transaction quantity were experienced by each auction house between Stages 2 and 3 with the setting up of KHAH, although there was no significant reduction in total quantity (Table 7).

Table 7. The comparison with mean of quantity in Stages 2 and 3 (unit: million bundles)

		TPAH	CHAH	TNAH	TCAH	KHAH	TOTAL
Mean	**Stage2**	2.6228	1.7537	1.1546	0.6347	n/a	6.1564
		(0.4315)	(0.2465)	(0.2115)	(0.1031)	n/a	(0.9416)
	Stage3	2.4910	1.0755	1.0480	0.5914	0.9210	6.1268
		(0.6551)	(0.2998)	(0.3415)	(0.1489)	(0.2936)	(1.5485)
Increased or decreased		decreased 5.03%	decreased 38.67%	decreased 9.23%	decreased 6.82%	n/a n/a	decreased 0.48%
$H_0 : \mu_2 = \mu_3$							
t-test		1.42	14.83	2.23	2.01	n/a	0.14
P-value		0.16	0.00‡	0.03†	0.05†	n/a	0.89

Note: ‡: p<0.01, †: p<0.05 and *: p<0.1, standard deviation listed in parenthesis and observations are 68 and 79 in Stages 2 and 3, respectively.

A number of findings are highlighted by the results presented in Table 7 and Figure16, with two major points arising from these results. Firstly, the introduction of the Dutch auction mechanism led to a rapid increase in the total transaction quantity of cut-flowers, thereby providing support for Proposition 2. Secondly, from 1996 onwards, although the total transaction quantity remained stable, there were no significant increases in the total transaction quantity with the setting up of the WISH system. This may possibly suggest that the cut-flower market in Taiwan has already achieved its saturation point.

A comparison of the results on transaction quantity growth in the three stages reveals that Proposition 2 is inconclusive, essentially because the market growth driven by IT intervention is ultimately limited by other factors, such as the limitations of Taiwan's cut-flower market scale and planted area (Table 8).

Table 8. The planted area of cut flowers, young flowers and potted flowers in Taiwan

Year	Total area		Cut flowers		Young flowers		Potted flowers	
	Area (hectare)	Growth (percent)	Area (hectare)	Growth (percent)	Area (hectare)	Growth (percent)	Area (hectare)	Growth (percent)
1990	6,178	n/a	3,218	n/a	2,700	n/a	260	n/a
1991	6,629	7.30	3,410	5.97	2,965	9.81	254	-2.31
1992	7,521	13.46	3,871	13.52	3,326	12.18	324	27.56
1993	9,019	19.92	4,729	22.16	3,931	18.19	359	10.80
1994	9,338	3.54	4,919	4.02	4,036	2.67	383	6.69
1995	9,577	2.56	4,789	-2.64	4,379	8.50	409	6.79
1996	9,911	3.49	4,777	-0.25	4,673	6.71	461	12.71
1997	10,384	4.77	4,761	-0.33	5,022	7.47	601	30.37
1998	10,142	-2.33	4,561	-4.20	4,889	-2.65	692	15.14
1999	10,743	5.93	4,789	5.00	5,288	8.16	666	-3.76
2000	10,960	2.02	5,007	4.55	5,201	-1.65	752	12.91
2001	10,422	-4.91	4,652	-7.09	5,037	-3.15	733	-2.53
2002	11,117	6.67	5,001	7.50	5,321	5.64	795	8.46
2003	11,540	3.80	4,519	-9.64	6,284	18.10	737	-7.30
2004	12,082	4.70	4,498	-0.46	6,823	8.58	761	3.26
2005	11,969	-0.94	4,061	-9.72	7,111	4.22	797	4.73
2006	12,784	6.81	4,265	5.02	7,695	8.21	824	3.39
2007	12,866	0.64	4,170	-2.23	7,915	2.86	781	-5.22
2008	12,520	-2.69	3,912	-6.19	7,808	-1.35	800	2.43

4.3.2.2 Stability

As shown in the above results, IT has played an enabling role in raising transaction quantity; however, this is clearly limited by market saturation. Nevertheless, IT can bring additional benefits, such as stability and efficiency, to both buyers and sellers through information sharing and visibility. Some important findings are provided by the evidence presented in this study on price stability and visibility between Stages 2 and 3. We find that as compared to Stage 2 prices, Stage 3 saw significant reductions in both daily and monthly prices (Tables 9 and 10, and Figure 17). This suggests that with greater information visibility, the suppliers were prepared to reduce their sale prices so as to successfully trade their cut-flowers with the various retailers, whilst the retailers were also able to achieve competitive purchasing prices.

Table 9. The comparison with mean and variance of daily price in Stages 2 and 3 (unit: dollars)

		TPAH	CHAH	TNAH	TCAH	KHAH	TOTAL
Mean	**Stage2**	57.25	50.78	45.77	44.24	n/a	52.26
		(12.89)	(11.18)	(10.21)	(10.98)	n/a	(11.49)
	Stage3	54.23	47.15	44.16	40.65	50.88	49.78
		(12.48)	(10.47)	(9.88)	(10.32)	(12.50)	(11.28)
Observations							
	Stage2	1722	1764	1744	1724	n/a	2011
	Stage3	2000	2023	1995	1972	2009	2336
$H_0: \mu_2 = \mu_3$	**t-test**	7.25	10.32	4.88	10.23	n/a	7.17
	P-value	0.00‡	0.00‡	0.00‡	0.01‡	n/a	0.00‡
$H_0: \sigma_2^2 = \sigma_3^2$	**F-test**	1.07	1.14	1.07	1.33	n/a	1.04
	P-value	0.16	0.00‡	0.16	0.01‡	n/a	0.40

Note: standard deviation listed in parenthesis and ‡: $p<0.01$, †: $p<0.05$ and *: $p<0.1$.

Table 10. The comparison with mean and variance of monthly price in Stages 2 and 3 (unit: dollars)

		TPAH	CHAH	TNAH	TCAH	KHAH	TOTAL
Mean	**Stage2**	58.16	51.93	46.94	44.68	n/a	52.77
		(9.16)	(7.54)	(6.72)	(6.86)	n/a	(8.00)
	Stage3	54.88	47.97	44.92	40.99	52.13	50.02
		(9.47)	(7.96)	(7.27)	(6.84)	(9.41)	(8.33)
$H_0: \mu_2 = \mu_3$	**t-test**	2.13	3.09	1.74	3.26	n/a	2.03
	P-value	0.05†	0.00‡	0.08*	0.00‡	n/a	0.04†
$H_0: \sigma_2^2 = \sigma_3^2$	**F-test**	1.07	1.11	1.17	1.01	n/a	1.08
	P-value	0.77	0.64	0.51	0.98	n/a	0.73

Note: ‡: $p<0.01$, †: $p<0.05$ and *: $p<0.1$, standard deviation listed in parenthesis and observations are 68 and 79 in Stages 2 and 3, respectively.

Those cut flowers initially characterized as having large trading ratios (trading quantity divided by total quantity), such as chrysanthemum, anthurium, roses, lilies, carnations and gladiolus (Appendix Tables I-IX), were also found to have significant reductions in their monthly prices between Stages 2 and 3, particularly with regard to anthurium, lilies and gladiolus (Appendix Tables X-XVIII).

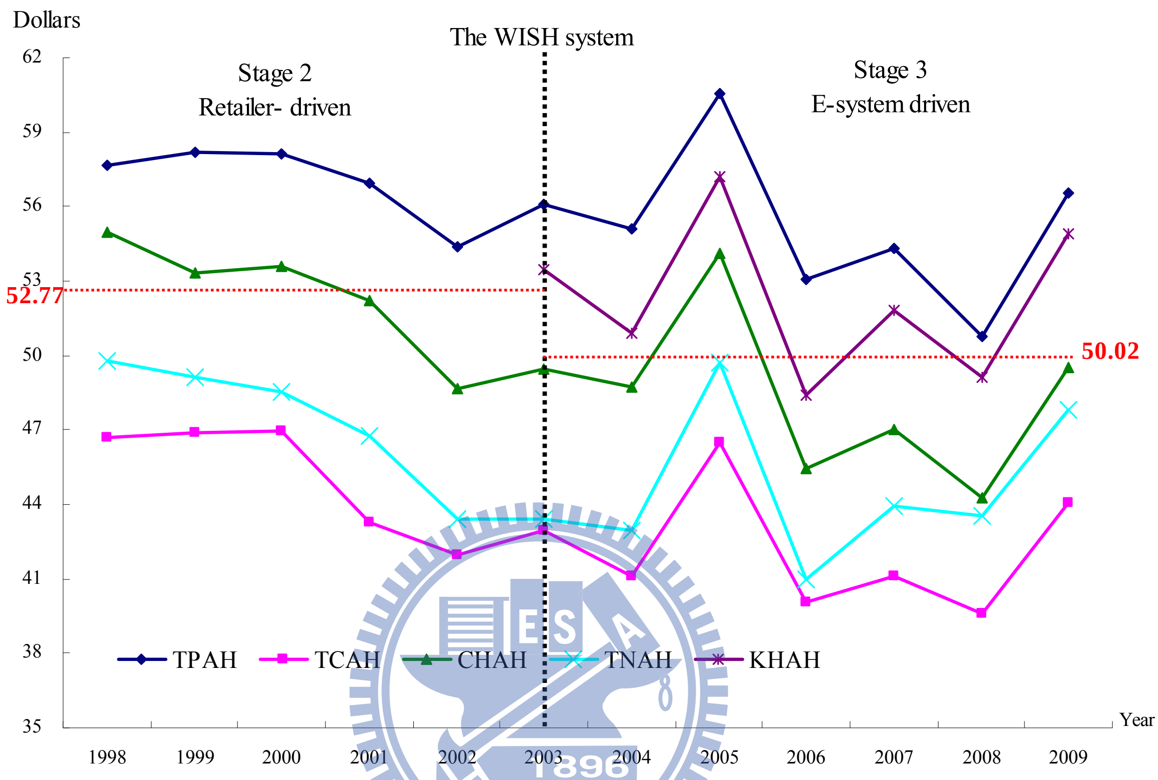


Figure 17. The Trend of price among different auction houses

Through the WISH platform, suppliers can check cut-flower prices in the different auction houses, thereby gaining information on the types of flowers they intend to provide to the auction houses one day in advance of the auction date. Similarly, retailers can check the daily cut-flower prices in the different auction houses to achieve competitive purchasing prices; as such, the daily price represents critical information on price visibility. We therefore adopt the Granger causality test to examine whether one time series can help to forecast another, and find that between January 1998 and August 2003, the prices in CHAH and TCAH could forecast the prices in TPAH, the prices in both TNAH and TCAH could effectively predict the prices in CHAH, the prices in TPAH and CHAH could successfully forecast the prices in TCAH, and the prices in CHAH could predict the prices in TNAH (Table 11 and Figure 18).

Table 11. Results of Granger causality test on daily prices in Stage 2

Dependent variable		**TPAH**	**CHAH**	**TNAH**	**TCAH**
TPAH (-1)	**Chi-sq.**	---	0.12	0.67	15.91
	P-value	---	0.72	0.41	0.00‡
CHAH (-1)	**Chi-sq.**	102.61	---	123.55	44.64
	P-value	0.00‡	---	0.00‡	0.00‡
TNAH (-1)	**Chi-sq.**	1.44	20.53	---	0.00
	P-value	0.23	0.00‡	---	0.97
TCAH (-1)	**Chi-sq.**	53.59	3.74	1.99	---
	P-value	0.00‡	0.05†	0.16	---

Note: ‡: p<0.01, †: p<0.05 and *: p<0.1

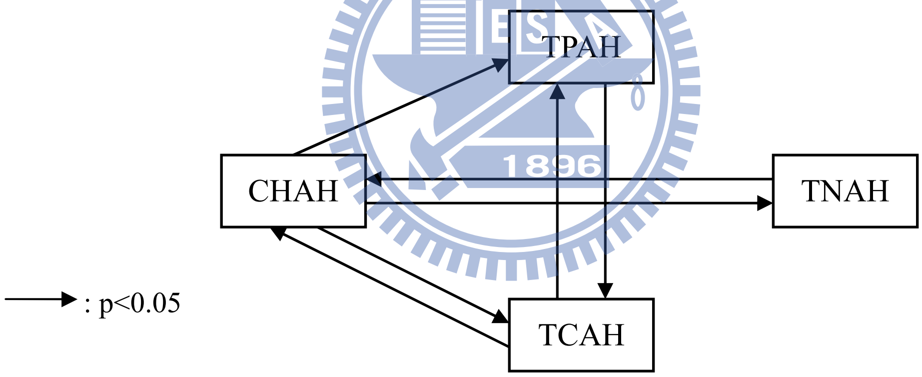


Figure 18. Interrelationship of prices among different auction houses in Stage 2

In Stage 3 (September 2003 to March 2010), most of the prices were found to be interrelated (Table 12 and Figure 19); therefore, daily prices clearly had significant relevance in this stage, as compared to the prices in all of the auction houses between Stages 2 and 3. This indicates that the degree of price visibility had become much greater in Stage 3 than in Stage 2.

Table 12. Results of Granger causality test on daily prices in Stage 3

Dependent variable		TPAH	CHAH	TNAH	TCAH	KHAH
TPAH (-1)	**Chi-sq.**	---	4.62	0.22	27.16	1.26
	P-value	---	0.03‡	0.64	0.00‡	0.26
CHAH (-1)	**Chi-sq.**	21.13	---	67.95	14.57	74.67
	P-value	0.00‡	---	0.00‡	0.00‡	0.00‡
TNAH (-1)	**Chi-sq.**	3.29	5.06	---	0.00	20.61
	P-value	0.07*	0.02‡	---	0.97	0.00‡
TCAH (-1)	**Chi-sq.**	11.27	0.00	14.47	---	8.94
	P-value	0.00‡	0.94	0.00‡	---	0.00
KHAH (-1)	**Chi-sq.**	29.66	26.44	34.46	4.89	---
	P-value	0.00‡	0.00‡	0.00‡	0.03†	---

Note: ‡: p<0.01, †: p<0.05 and *: p<0.1

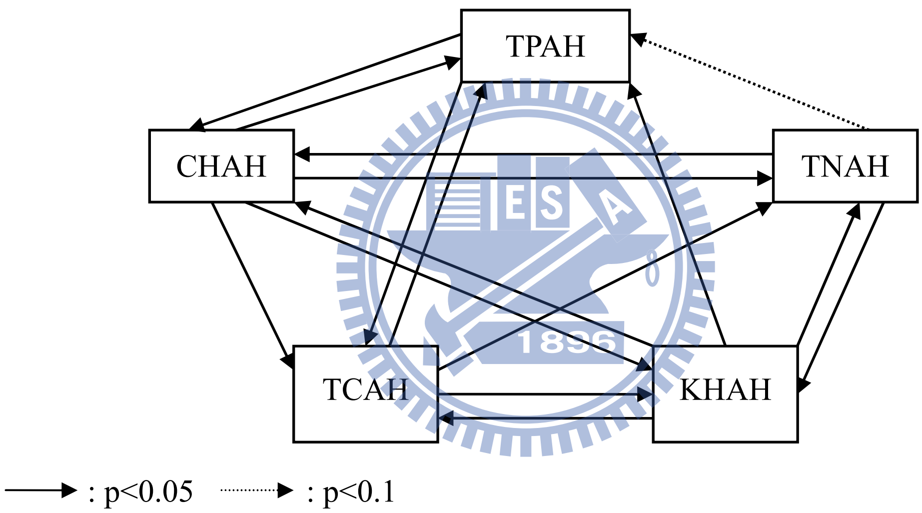


Figure 19. Interrelationship of prices among different auction houses in Stage 3

During the period from January 1998 to August 2003, the prices in TPAH and TCAH were interrelated essentially because these two auction houses were heavily dependent upon the same sources of supply. The prices in CHAH and TCAH were also interrelated, again due to the same sources of supply. In specific terms, the interrelated prices in CHAH and TNAH were attributable to the sales in these two auction houses being heavily dependent upon southern Taiwan. Since most of the TPAH supplies were also heavily dependent upon the same sources of supply as CHAH, the prices in CHAH could effectively predict the prices in TPAH.

Although the daily prices amongst the various agents became far more visible in Stage 3, prices in TCAH were found to be of little use in predicting prices in CHAH, essentially because of their different trading ratios in the various cut-flowers. Furthermore, the prices in TPAH could not forecast the prices in TNAH and KHAH since the sales of TPAH are concentrated in northern Taiwan, and not southern Taiwan, which is the main sales area for TNAH and KHAH. The prices in TNAH could not predict those in TCAH since, unlike TNAH, the sales in TCAH are concentrated in central Taiwan.

A comparison of daily prices in the different auction houses, particularly CHAH and TCAH, shows that daily price volatility was lower in Stage 3 than in Stage 2 (Table 9), thereby indicating that daily prices became far more stable in Stage 3 than in Stage 2; however, no significant differences were found in monthly price volatility between Stages 2 and 3 (Table 10). Co-integration analysis was also undertaken, based upon the following four analytical steps: (i) examination of the stationarity of each variable using the unit root test and the same integrated order; (ii) a check of the VAR lag order selection criteria; (iii) the adoption of the Johansen co-integration test; and (iv) the use of the unit root test for the residual terms. The results reveal long-run price equilibrium (Tables 13-20) to support our Proposition in this study.

Three major points arise from these results, as follows. Firstly, the introduction of the WISH system has led to a reduction in price volatility, in turn leading to greater price stability. Secondly, with greater price visibility, suppliers have tended to reduce their sales price in order to successfully trade their cut-flowers with retailers, whilst retailers have consequently gained competitive purchasing prices. Thirdly, the results of our co-integration analysis reveal long-run price equilibrium. The overall results on Stages 2 and 3 provide clear support for Proposition 3 in this study; therefore, as a result of IT intervention, as an external condition, prices have become more stable in the SCNs due to greater visibility, thereby leading to long-run equilibrium.

Table 13. Stationarity and integrated order of each variable in Stage 2

		TPAH	CHAH	TNAH	TCAH
Level	**ADF-Statistic**	-0.58	-0.49	-0.54	-0.60
	P-value	0.46	0.50	0.48	0.46
1st Difference	**ADF-Statistic**	-9.32	-8.25	-8.82	-9.76
	P-value	0.00‡	0.00‡	0.00‡	0.00‡
***I*(?)**		*I*(1)	*I*(1)	*I*(1)	*I*(1)

Note: ‡: p<0.01, †: p<0.05 and *: p<0.1

Table 14. The lag order selection criteria in Stage 2

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-578.5842	NA	1705.377	18.79304	18.93027	18.84692
1	-545.2277	61.33295*	975.5943*	18.23315*	18.91932*	18.50256*
2	-533.0512	20.81782	1111.254	18.35649	19.59160	18.84143
3	-518.1680	23.52516	1171.756	18.39251	20.17656	19.09298
4	-507.5354	15.43439	1439.055	18.56566	20.89864	19.48165
5	-497.3336	13.49266	1830.942	18.75270	21.63462	19.88421

Note: * indicates lag order selected by the criterion, LR: sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion and HQ: Hannan-Quinn information criterion.

Table 15. Results of Johansen co-integration test in Stage 2

Hypothesized	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.490440	84.20084	40.17493	0.0000
At most 1 *	0.302938	39.70317	24.27596	0.0003
At most 2 *	0.211320	15.88501	12.32090	0.0122
At most 3	0.003282	0.216945	4.129906	0.6983

Note: Trace test indicates 3 co-integrating eqn(s) at the 0.05 level, it included observations: 66 after adjustments and lags interval is 1, and trend assumption represents no deterministic trend. * denotes rejection of the hypothesis at the 0.05 level. ** denotes MacKinnon-Haug-Michelis (1999) p-values

Table 16. Results of unit root test for residual terms in Stage 2

		Residual 1	Residual 2	Residual 3	Residual 4
Level	**t-Statistic**	-8.05	-8.17	-8.30	-8.11
	P-value	0.00‡	0.00‡	0.00‡	0.00‡

Note: ‡: p<0.01, †: p<0.05 and *: p<0.1

Table 17. Sationarity and integrated order of each variable in Stage 3

		TPAH	CHAH	TNAH	TCAH	KHAH
Level	**ADF-Statistic**	-0.89	-0.77	-0.69	-0.87	-0.75
	P-value	0.33	0.38	0.48	0.34	0.46
1st Difference	**ADF-Statistic**	-10.58	-9.98	-9.87	-11.10	-10.25
	P-value	0.00‡	0.00‡	0.00‡	0.00‡	0.00‡
***I*(?)**		*I*(1)	*I*(1)	*I*(1)	*I*(1)	*I*(1)

Note: ‡: p<0.01, †: p<0.05 and *: p<0.1

Table 18. The lag order selection criteria in Stage 3

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-843.2744	NA	11775.80	23.56318	23.72128	23.62612
1	-784.5954	107.5782	4629.487*	22.62765*	23.57626*	23.00529*
2	-767.7164	28.60049	5859.995	22.85323	24.59235	23.54558
3	-746.6444	32.77862	6705.366	22.96235	25.49197	23.96940
4	-728.4795	25.73368	8518.752	23.15221	26.47235	24.47396
5	-695.5835	42.03380*	7435.403	22.93287	27.04352	24.56933

Note: * indicates lag order selected by the criterion, LR: sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion and HQ: Hannan-Quinn information criterion.

Table 19. Results of Johansen co-integration test in Stage 3

Hypothesized	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.474870	103.6535	60.06141	0.0000
At most 1 *	0.262769	54.05705	40.17493	0.0012
At most 2 *	0.246666	30.58325	24.27596	0.0071
At most 3	0.104808	8.773286	12.32090	0.1827
At most 4	0.003217	0.248081	4.129906	0.6775

Note: Trace test indicates 3 co-integrating eqn(s) at the 0.05 level

Table 20. Results of unit root test for residual terms in Stage 3

		Residual 1	Residual 2	Residual 3	Residual 4	Residual 5
Level	**t-Statistic**	-8.89	-8.70	-8.62	-8.84	-8.55
	P-value	0.00‡	0.00‡	0.00‡	0.00‡	0.00‡

Note: ‡: $p<0.01$, †: $p<0.05$ and *: $p<0.1$

4.3.2.3 Efficiency

According to a comparison between Stages 2 and 3 of all surplus ratios, the setting up of the WISH system in September 2003 has led to significant reductions in surplus ratios for all of the auction houses (Table 21). This indicates that significant improvements have been achieved in operational efficiency. The monthly surplus ratio in Stage 2 was 5.02 percent (Figure 20), whereas this was effectively reduced to a monthly average of 3.60 percent in Stage 3; indeed, significant improvements in surplus ratios were experienced by all of the auction houses between Stages 2 and 3.

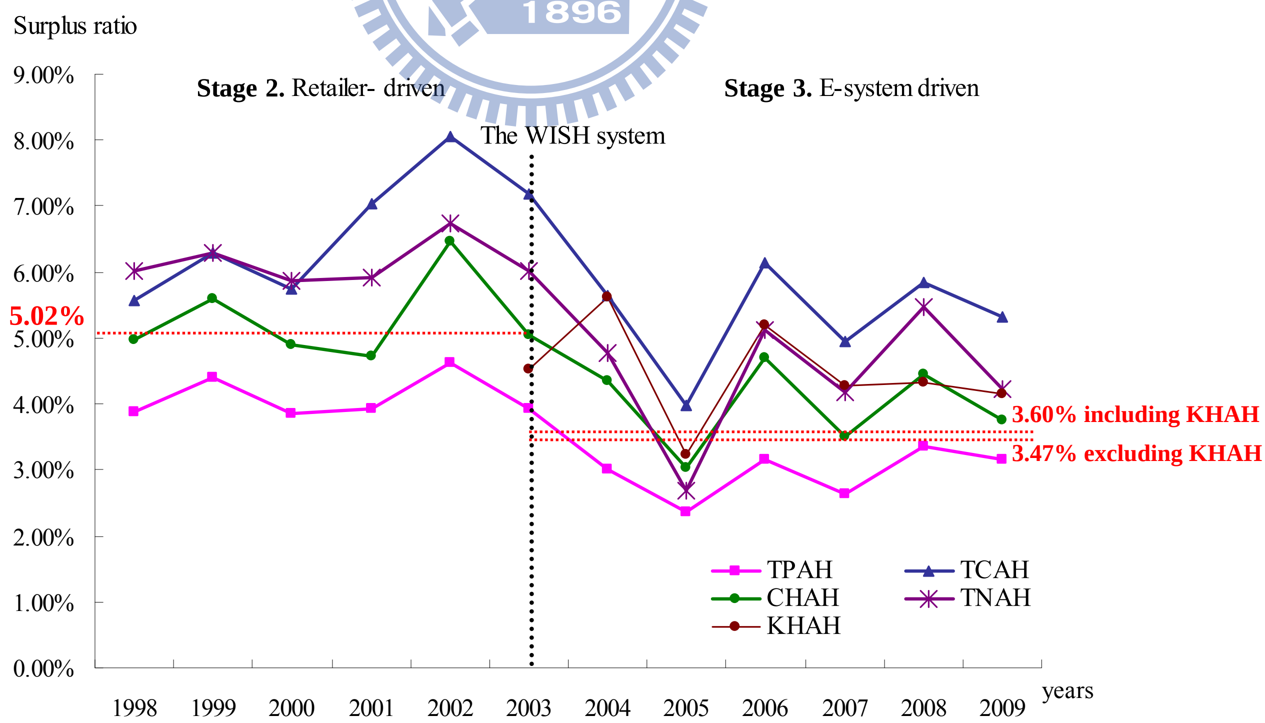


Figure 20. The trend of surplus ratio among different auction houses

Table 21. The comparison with mean and variance of surplus ratio in Stages 2 and 3

		TPAH	CHAH	TNAH	TCAH	KHCH	TOTAL
Mean	**Stage2**	4.04%	5.26%	6.01%	6.50%	n/a	5.02%
		(0.0174)	(0.0219)	(0.0242)	(0.0255)	n/a	(0.0202)
	Stage3	2.70%	3.77%	4.03%	5.08%	4.50%	3.60%
		(0.0155)	(0.0197)	(0.0232)	(0.0221)	(0.0280)	(0.0189)
$H_0 : \mu_2 = \mu_3$							
t-test		4.93	4.36	5.05	3.62	n/a	4.39
P-value		0.00‡	0.00‡	0.00‡	0.00‡	n/a	0.00‡
$H_0 : \sigma_2^2 = \sigma_3^2$							
F-test		1.25	1.23	1.09	1.33	n/a	1.15
P-value		0.35	0.38	0.73	0.24	n/a	0.57

Note: Surplus ratio equals surplus divided by supply, ‡: p<0.01, †: p<0.05 and *: p<0.1, standard deviation listed in parenthesis and observations are 68 and 79 in Stages 2 and 3, respectively.

Two major points arise from these results, as follows. Firstly, the establishment of the WISH system has alleviated much of the uncertainty in both supply and demand through information sharing; thus, all of agents in the auction houses are able to coordinate their operations in demand management and transshipment systems across the SCNs. Consequently, surplus ratios have been significantly reduced in Stage 3 in all of the auction houses.

Secondly, the overall annual wastage losses on cut-flowers were previously estimated to be NT$205.31 million from January 1998 to August 2003, whereas between September 2003 and July 2008, they were effectively reduced to an annual average of NT$139.50 million; thus, the annual reduction in wastage losses amounts to an average of NT$ 65.81 million. This indicates support for Proposition 4 in this study. Therefore, with the introduction of IT, as the intervention of an external condition in the supply chain, operational efficiency has been increased and wastage losses have been reduced.

5. CONCLUSIONS

5.1 Concluding Remark

This study describes the process of evolution of supply chains within the cut-flower industry of Taiwan, placing particular focus on a discussion of supply chain evolution enabled by the Dutch auction mechanism and the 'Wholesale Information Sharing Hotline' (WISH) system. From a macro-study perspective, we divide the evolutionary process into three distinct supplier-driven, retailer-driven and e-system-driven stages, in order to explore the forces driving the evolution of the cut-flower supply chains, and find that the forces triggering such evolution were the interactions between the external conditions and internal factors; thus, successful evolution can only occur if the overall performance of the SCN is significantly improved.

Based upon our recognition of a SCN as a CAS, we have been able to investigate the issue of the dynamic evolution of SCNs by examining the four propositions developed in this study. The real-world case of the cut-flower supply chain in Taiwan is used to identify the observable patterns during the three distinct stages arising from the changes in agents, decision rules and connectively, all of which are based upon adaptation to the introduction of IT.

Between Stages 1 and 2, with IT forcing the introduction of the Dutch auction mechanism, the changes in the associated agents resulted in the foundation of four auction houses, the integration of operations and transactions, and the introduction and application of common standards of quality and packing amongst all suppliers. The changes in decision rules amongst sellers were largely characterized by their supply of cut-flowers to these auction houses, whilst the changes in decision rules amongst the retailers were their subsequent purchases of flowers in the neighboring auction houses. Suppliers and retailers were consequently brought into frequent contact through their auction house connections based upon contractual arrangements. The evolutionary outcome of this was soaring growth in cut flowers, thereby providing support for Propositions 1 and 2 in this study.

Between Stages 2 and 3, with IT forcing the establishment of the WISH system, the changes in the agents were the integration of information systems amongst buyers and sellers in all of the auction houses, the integration of coding systems by suppliers across different supply chains, and coordinated operations through demand management and transshipment systems.

In Stage 3, as a result of their enhanced understanding of integrated intelligence brought about by the WISH system and information exchange, both sellers and buyers alike changed their decision rules. The setting up of the WISH system has therefore provided loose connections amongst agents which has ultimately led to rapid responses to changes amongst both suppliers and retailers.

The evolutionary outcomes are price visibility and stability and a reduction in wastage losses, thereby providing support for Proposition 1; however, Proposition 2 in this study is found to be inconclusive, essentially because the market growth driven by IT is limited by other factors, such as market saturation and the number of suppliers and retailers. The evolutionary outcomes between Stages 2 and 3 are confirmed, from a micro-study perspective, by our empirical analyses of the effectiveness of IT, using time-series data obtained from the WISH system.

Our results reveal that the introduction of the WISH system has effectively reduced price volatility and improved price stability. With greater price visibility, suppliers have tended to reduce their sale prices so as to successfully trade their cut-flowers with retailers, whilst retailers have consequently gained competitive purchasing prices, leading to an overall decline in prices, and a long-run price equilibrium phenomenon between Stages 2 and 3, thereby providing further support for Proposition 3.

Finally, as regards operational efficiency, the establishment of the WISH system has alleviated much of the uncertainty in both supply and demand across SCNs through demand management and transshipment systems, thereby reducing surplus ratios in all of the auction houses in Stage 3. Indeed, the overall annual wastage losses for cut-flowers has been effectively reduced to an average of NT$ 65.81 million, thereby providing support for Proposition 4.

5.2 Limitations

Considering the problem of the generalization in this research, despite, we adopted an example of Taiwan's cut-flower industry and collectively gathered overall data to investigate the supply chain evolution; the fact that this research approach is limited by a case study of cut-flower industry, whilst the results drawn from this study are confident in evidence. Generally, case studies are recognized as an especially valuable in exploratory research; indeed, it is a good approach in attempt to understand what and why observed evolutionary phenomena occur; therefore, a historical reconstruction is either more feasible or more desirable in this study.

In performing research into SCN evolution, some variables, such as external condition, internal factors and indicators, have not been systemically and structurally analyzed to clarify their interrelationships in this study. The extremely high and rigorous methodological standards will be developed in the future, in order to support such systemic analyses, not only for simplifying the complexity of the overall SCN, but also for providing the advanced technique of analysis.

5.3 Direction of Future Works

This study focuses primarily on the evolutionary process of supply chains through IT in distinct evolutionary stages. There is, as yet, relatively little evidence on the evolution of SCNs, despite the fact that it is very clear that this is an important trend in SCM. This is an issue which is of considerable interest and importance, clearly in need of further study by the research community. Future studies should try to place greater emphasis on the types of mechanisms through embracing the IT system, which might better facilitate the successful supply chain evolution, as well as the types of IT that can provide effective support for supply chain evolution in both vertical and horizontal dimensions. Indeed, network characteristics in terms of most aspects of coordinative strategies through IT likely have a conspicuous effect on the evolution of supply chains; it deserves enhanced attention in future research.

According to our analyses, IT forcing the growth of market is limited by other factors, such as market saturation and planted area; therefore, Proposition 2 is inconclusive by our investigation. This study suggests that Proposition 2 will be evidenced in future works if exports of cut-flowers increase, if the WISH system with the e-auction mechanism is applied to different countries; the potential effectiveness of IT will bring the increase in transaction quantity to grow the cut-flower market afterwards.

Some of the potential lessons identified in this study can help to address the special issues associated with certain questions on SCM. With a external environment having been identified as both shaping, and being shaped, by evolution, this gives rise to other associated questions with regard to the kinds of environmental impacts that have effects on the evolution of a SCN, both at individual and system levels, the new rules and norms that will ultimately alter the behavior, structures and patterns of agents, and the ways in which the evolution of a SCN can trigger further environmental changes.

Finally, in performing research into SCN evolution, we believe that extremely high and rigorous methodological standards will need to be developed, adopted and upheld in order to clarify the complexity of the overall system in the future works.

5.4 Managerial Implications

The idea of managing the whole SCN to achieve global optimization through the advancement of network benefits provides an engaging vision and a certain requirement for appropriate decision-making by managers during the process of supply chain evolution; and indeed, the empirical examination of the propositions of this study gives rise to important implications, all of which are summarized below. This study confirms the supply chain evolution, IT as a critical external condition intervenes in the SCN, which triggers such evolution in three evolutionary stages, summarizing some of the important implications as follows:

Firstly, managers need to be able to respond rapidly to the changing environments and adapt to such changes by modifying the objectives and strategies of the SCN. From our analysis of the evolutionary process within the cut-flower supply chain in Taiwan, during the introductory and secondary stages, agents were found to be sensitive to the changes that are brought about by the introduction of Dutch auction mechanism, with their primary objective subsequently shifting to the improvement of auction operations. Their SCM strategies were thereby modified towards greater focus on efficient operational processes and workflow integration.

Between the second and final stages, with IT forcing the establishment of the WISH system, all of auction houses focused on integrating their information systems in order to achieve much more comprehensive sharing of information, thereby reducing much of the uncertainty in both supply and demand. A major operational strategy within SCNs is the coordination of the demand management and transshipment systems across SCNs in order to reduce the waste loss.

Next, the adoption of appropriate IT can assist in the achievement and advancement of supply chain evolution, since IT plays an enabling role in the sharing of information. Focusing on the evolution of IT, compatible technologies have advanced from EDI (Electronic Data Interchange) to web-based and RFID-enabled mechanisms with corresponding coordination having also evolved from VMI to CPFR and RFID-enabled (Pramatari, 2007). EDI is a common transaction format which allows enterprises to electronically transmit data (Simchi-Levi et al., 2008). RFID (Radio Frequency Identification) is an important technology development for the sophisticated replacement for bar codes. Although, RFID is still in the early stages of adoptions, it has been widely supported by some large companies such as HP and Wal-Mart (Simchi-Levi et al., 2008).

With the introduction of Dutch auction mechanism, the benefits accrued by participants between 1989 and 2003 include rapid growth in sales and improvements in auction operations. Such an e-auction mechanism is particularly useful in cases of uncertain sources of supply (involving, for example, agri-products) or uncertain customer demand, such as the demand of cut-flowers (Hartley et al., 2004). The establishment of the WISH system results in decrease of volatility of price to being more stable and visible; the price declines and has a long-run equilibrium. Indeed, establishing the WISH system leads the reduction of surplus ratios and overall annual waste loss. Therefore, the IT system has enabled traders to achieve mutual reinforcement through information sharing, taking some benefits themselves.

An essential task in modern-day SCM is the selection of the appropriate IT tools that will effectively facilitate coordination. RFID is now the most widely prevailing technology, and there is still much untapped potential for use in SCM. Whilst the WISH web-based platform provides such support for information exchange in Taiwan's cut-flower supply chains, RFID technology can also be used to further promote coordination in unique product identification and in tracing back sources of supply and trading processes.

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APPENDIX

Table I. Trade ratio of FC-chrysanthemum between Stage 2 and 3

		TPAH	CHAH	TNAH	TCAH	KHCH	TOTAL
Mean	**Stage2**	2.01%	2.01%	2.11%	0.40%	n/a	7.90%
		(0.0056)	(0.0059)	(0.0039)	(0.0008)	n/a	(0.0144)
	Stage3	1.08%	1.12%	1.11%	0.24%	1.03%	4.60%
		(0.0034)	(0.0036)	(0.0026)	(0.0007)	(0.0031)	(0.0110)
$H_0{:}\mu_2 = \mu_3$							
t-test		11.93	27.96	18.37	13.20	n/a	15.61
P-value		0.00‡	0.00‡	0.00‡	0.00‡	n/a	0.00‡

Note: Trade ratio equals transaction quantity of a category of cut-flower divided by total transaction quantity, ‡: p<0.01, †: p<0.05 and *: p<0.1, standard deviation listed in parenthesis and observations are 68 and 76 in Stages 2 and 3, respectively.

Table II. Trade ratio of FD-chrysanthemum between stage 2 and 3

		TPAH	CHAH	TNAH	TCAH	KHCH	TOTAL
Mean	**Stage2**	2.57%	5.43%	3.94%	0.69%	n/a	12.61%
		(0.0082)	(0.0089)	(0.0065)	(0.0015)	n/a	(0.0227)
	Stage3	2.29%	2.44%	2.49%	0.54%	2.32%	10.09%
		(0.0066)	(0.0067)	(0.0056)	(0.0014)	(0.0063)	(0.0209)
$H_0{:}\mu_2 = \mu_3$							
t-test		2.30	23.01	14.36	5.82	n/a	6.95
P-value		0.02†	0.00‡	0.00‡	0.00‡	n/a	0.00‡

Note: ‡: p<0.01, †: p<0.05 and *: p<0.1 and standard deviation listed in parenthesis

Table III. Trade ratio of FB-anthurium between stage 2 and 3

		TPAH	CHAH	TNAH	TCAH	KHCH	TOTAL
Mean	**Stage2**	6.05%	3.25%	2.40%	1.87%	n/a	13.54%
		(0.0151)	(0.0093)	(0.0075)	(0.0054)	n/a	(0.0350)
	Stage3	5.60%	2.35%	2.66%	1.79%	1.03%	14.14%
		(0.0159)	(0.0067)	(0.0084)	(0.0047)	(0.0031)	(0.0376)
$H_0{:}\mu_2 = \mu_3$							
t-test		1.74	6.71	1.98	0.93	n/a	0.98
P-value		0.08*	0.00‡	0.05†	0.35	n/a	0.33

Note: ‡: p<0.01, †: p<0.05 and *: p<0.1 and standard deviation listed in parenthesis

Table IV. Trade ratio of FR-rose between stage 2 and 3

		TPAH	CHAH	TNAH	TCAH	KHCH	TOTAL
Mean	**Stage2**	3.95%	1.76%	0.90%	1.08%	n/a	7.67%
		(0.0093)	(0.0039)	(0.0022)	(0.0028)	n/a	(0.0170)
	Stage3	2.59%	0.81%	0.70%	0.72%	0.88%	5.71%
		(0.0053)	(0.0022)	(0.0019)	(0.0015)	(0.0027)	(0.0113)
$H_0 : \mu_2 = \mu_3$							
t-test		10.91	17.91	5.80	9.90	n/a	8.25
P-value		0.00‡	0.00‡	0.00‡	0.00‡	n/a	0.00‡

Note: ‡: p<0.01, †: p<0.05 and *: p<0.1 and standard deviation listed in parenthesis

Table V. Trade ratio of FE-chrysanthemum between stage 2 and 3

		TPAH	CHAH	TNAH	TCAH	KHCH	TOTAL
Mean	**Stage2**	2.74%	1.58%	0.98%	0.68%	n/a	5.97%
		(0.0039)	(0.0027)	(0.0020)	(0.0008)	n/a	(0.0071)
	Stage3	2.40%	1.35%	1.37%	0.62%	1.03%	7.04%
		(0.0033)	(0.0020)	(0.0040)	(0.0010)	(0.0032)	(0.0096)
$H_0 : \mu_2 = \mu_3$							
t-test		5.67	6.00	7.27	3.73	n/a	7.51
P-value		0.00‡	0.00‡	0.00‡	0.00‡	n/a	0.00‡

Note: ‡: p<0.01, †: p<0.05 and *: p<0.1 and standard deviation listed in parenthesis

Table VI. Trade ratio of FS-lily between stage 2 and 3

		TPAH	CHAH	TNAH	TCAH	KHCH	TOTAL
Mean	**Stage2**	3.61%	2.03%	1.27%	0.80%	n/a	7.70%
		(0.0092)	(0.0027)	(0.0042)	(0.0022)	n/a	(0.0201)
	Stage3	5.25%	1.87%	1.91%	0.99%	1.70%	11.72%
		(0.0087)	(0.0020)	(0.0071)	(0.0022)	(0.0046)	(0.0210)
$H_0 : \mu_2 = \mu_3$							
t-test		11.00	2.39	6.45	5.14	n/a	11.69
P-value		0.00‡	0.02†	0.00‡	0.00‡	n/a	0.00‡

Note: ‡: p<0.01, †: p<0.05 and *: p<0.1 and standard deviation listed in parenthesis

Table VII. Trade ratio of FA8-carnation between stage 2 and 3

		TPAH	CHAH	TNAH	TCAH	KHCH	TOTAL
Mean	**Stage2**	1.06%	0.74%	0.48%	0.23%	n/a	2.50%
		(0.0109)	(0.0062)	(0.0049)	(0.0025)	n/a	(0.0241)
	Stage3	0.82%	0.33%	0.38%	0.18%	0.88%	2.01%
		(0.0109)	(0.0034)	(0.0046)	(0.0025)	(0.0027)	(0.0242)
$H_0: \mu_2 = \mu_3$							
t-test		1.33	4.89	1.31	1.18	n/a	1.23
P-value		0.19	0.00‡	0.19	0.24	n/a	0.22

Note: ‡: p<0.01, †: p<0.05 and *: p<0.1 and standard deviation listed in parenthesis

Table VIII. Trade ratio of FK-lily between stage 2 and 3

		TPAH	CHAH	TNAH	TCAH	KHCH	TOTAL
Mean	**Stage2**	1.39%	1.00%	0.64%	0.33%	n/a	3.35%
		(0.0041)	(0.0030)	(0.0020)	(0.0009)	n/a	(0.0096)
	Stage3	1.56%	0.60%	0.69%	0.32%	0.61%	3.79%
		(0.0054)	(0.0019)	(0.0024)	(0.0010)	(0.0022)	(0.0116)
$H_0: \mu_2 = \mu_3$							
t-test		2.14	9.60	1.52	0.79	n/a	2.46
P-value		0.03†	0.00‡	0.13	0.43	n/a	0.02†

Note: ‡: p<0.01, †: p<0.05 and *: p<0.1 and standard deviation listed in parenthesis

Table IX. Trade ratio of FG-gladiolus between stage 2 and 3

		TPAH	CHAH	TNAH	TCAH	KHCH	TOTAL
Mean	**Stage2**	1.50%	1.00%	0.90%	0.25%	n/a	3.94%
		(0.0074)	(0.0030)	(0.0019)	(0.0008)	n/a	(0.0117)
	Stage3	0.93%	0.60%	0.58%	0.17%	0.55%	2.84%
		(0.0059)	(0.0019)	(0.0019)	(0.0007)	(0.0017)	(0.0105)
$H_0: \mu_2 = \mu_3$							
t-test		5.09	9.60	9.96	6.56	n/a	5.95
P-value		0.00‡	0.00‡	0. 00‡	0.00‡	n/a	0.00‡

Note: ‡: p<0.01, †: p<0.05 and *: p<0.1 and standard deviation listed in parenthesis

Table X. Comparison of monthly price of FC-chrysanthemum between stage 2 and 3 (unit: dollars)

		TPAH	CHAH	TNAH	TCAH	KHCH	TOTAL
Mean	**Stage2**	48.07	48.59	48.24	38.01	n/a	47.91
		(12.57)	(12.29)	(12.71)	(9.92)	n/a	(12.32)
	Stage3	49.19	45.64	46.38	35.71	50.39	47.36
		(14.78)	(13.15)	(13.52)	(9.58)	(15.45)	(13.83)
$H_0:\mu_2 = \mu_3$							
t-test		0.49	1.40	0.86	1.42	n/a	0.25
P-value		0.62	0.17	0.39	0.16	n/a	0.80
$H_0:\sigma_2^2 = \sigma_3^2$							
F-test		1.38	1.15	1.13	1.07	n/a	1.26
P-value		0.17	0.56	0.60	0.77	n/a	0.32

Note: ‡: p<0.01, †: p<0.05 and *: p<0.1 and standard deviation listed in parenthesis

Table XI. Comparison of monthly price of FD-chrysanthemum between stage 2 and 3 (unit: dollars)

		TPAH	CHAH	TNAH	TCAH	KHCH	TOTAL
Mean	**Stage2**	40.21	41.00	41.24	30.57	n/a	40.44
		(7.40)	(7.58)	(7.86)	(5.51)	n/a	(7.50)
	Stage3	40.68	39.16	40.27	30.66	43.30	40.41
		(11.50)	(11.71)	(11.92)	(8.76)	(13.24)	(11.75)
$H_0:\mu_2 = \mu_3$							
t-test		0.29	1.10	0.58	0.08	n/a	0.02
P-value		0.77	0.27	0.57	0.94	n/a	0.99
$H_0:\sigma_2^2 = \sigma_3^2$							
F-test		2.42	2.39	2.30	2.53	n/a	2.45
P-value		0.00‡	0.00‡	0.00‡	0.00‡	n/a	0.00‡

Note: ‡: p<0.01, †: p<0.05 and *: p<0.1 and standard deviation listed in parenthesis

Table XII. Comparison of monthly price of FB-anthurium between stage 2 and 3 (unit: dollars)

		TPAH	CHAH	TNAH	TCAH	KHCH	TOTAL
Mean	**Stage2**	14.27	13.49	11.78	11.64	n/a	13.29
		(3.97)	(4.31)	(2.95)	(3.44)	n/a	(3.96)
	Stage3	11.56	12.28	10.44	9.93	11.80	11.30
		(2.38)	(2.73)	(1.96)	(2.07)	(2.27)	(2.31)
$H_0:\mu_2 = \mu_3$							
t-test		5.10	2.06	3.30	3.70	n/a	3.79
P-value		0.00‡	0.04†	0.00‡	0.00‡	n/a	0.00‡
$H_0:\sigma_2^2 = \sigma_3^2$							
F-test		2.77	2.48	2.25	2.76	n/a	2.94
P-value		0.00‡	0.00‡	0.00‡	0.00‡	n/a	0.00‡

Note: ‡: p<0.01, †: p<0.05 and *: p<0.1 and standard deviation listed in parenthesis

Table XIII. Comparison of monthly price of FR-rose between stage 2 and 3 (unit: dollars)

		TPAH	CHAH	TNAH	TCAH	KHCH	TOTAL
Mean	**Stage2**	81.78	77.96	68.43	75.19	n/a	78.59
		(31.76)	(29.87)	(25.87)	(28.74)	n/a	(30.19)
	Stage3	93.28	80.21	72.54	84.42	87.14	87.59
		(27.05)	(22.64)	(20.69)	(25.79)	(22.99)	(24.93)
$H_0:\mu_2=\mu_3$							
t-test		2.37	0.52	1.07	2.04	n/a	1.98
P-value		0.02†	0.61	0.29	0.04†	n/a	0.05*
$H_0:\sigma_2^2=\sigma_3^2$							
F-test		1.38	1.74	1.56	1.24	n/a	1.47
P-value		0.18	0.02†	0.06*	0.37	n/a	0.11

Note: ‡: p<0.01, †: p<0.05 and *: p<0.1 and standard deviation listed in parenthesis

Table XIV. Comparison of monthly price of FE-chrysanthemum between stage 2 and 3 (unit: dollars)

		TPAH	CHAH	TNAH	TCAH	KHCH	TOTAL
Mean	**Stage2**	35.62	33.91	35.05	33.95	n/a	34.98
		(8.51)	(8.33)	(8.44)	(8.45)	n/a	(8.23)
	Stage3	36.14	35.65	35.55	35.50	36.15	35.90
		(13.27)	(13.35)	(13.06)	(12.73)	(13.45)	(13.10)
$H_0:\mu_2=\mu_3$							
t-test		0.27	0.92	0.27	0.85	n/a	0.50
P-value		0.78	0.35	0.79	0.40	n/a	0.62
$H_0:\sigma_2^2=\sigma_3^2$							
F-test		2.43	2.57	2.40	2.27	n/a	2.53
P-value		0.00‡	0.00‡	0. 00‡	0. 00‡	n/a	0. 00‡

Note: ‡: p<0.01, †: p<0.05 and *: p<0.1 and standard deviation listed in parenthesis

Table XV. Comparison of monthly price of FS-lily between stage 2 and 3 (unit: dollars)

		TPAH	CHAH	TNAH	TCAH	KHCH	TOTAL
Mean	**Stage2**	140.66	126.55	111.20	122.09	n/a	130.23
		(32.93)	(29.51)	(28.32)	(30.74)	n/a	(31.08)
	Stage3	126.63	115.73	105.70	110.36	119.61	119.28
		(31.58)	(27.91)	(27.86)	(28.20)	(29.06)	(29.70)
$H_0:\mu_2=\mu_3$							
t-test		2.63	2.28	1.18	2.40	n/a	2.18
P-value		0.00‡	0.02†	0.24	0.02†	n/a	0.03†
$H_0:\sigma_2^2=\sigma_3^2$							
F-test		1.09	1.12	1.03	1.19	n/a	1.10
P-value		0.73	0.64	0.89	0.47	n/a	0.70

Note: ‡: p<0.01, †: p<0.05 and *: p<0.1 and standard deviation listed in parenthesis

Table XVI. Comparison of monthly price of FA8-carnation between stage 2 and 3 (unit: dollars)

		TPAH	CHAH	TNAH	TCAH	KHCH	TOTAL
Mean	**Stage2**	31.75	30.55	29.20	30.43	n/a	30.70
		(10.44)	(9.53)	(8.93)	(9.29)	n/a	(9.42)
	Stage3	32.22	29.46	28.26	28.90	28.37	30.25
		(9.87)	(9.53)	(9.36)	(10.03)	(9.29)	(9.16)
$H_0{:}\mu_2=\mu_3$							
t-test		0.28	0.69	0.61	0.94	n/a	0.29
P-value		0.78	0.49	0.54	0.35	n/a	0.77
$H_0{:}\sigma_2^2=\sigma_3^2$							
F-test		1.12	1.00	1.10	1.17	n/a	1.06
P-value		0.64	1.00	0.69	0.52	n/a	0.82

Note: ‡: p<0.01, †: p<0.05 and *: p<0.1 and standard deviation listed in parenthesis

Table XVII. Comparison of monthly price of FK-lily between stage 2 and 3 (unit: dollars)

		TPAH	CHAH	TNAH	TCAH	KHCH	TOTAL
Mean	**Stage2**	125.81	116.57	104.33	109.84	n/a	117.27
		(29.56)	(28.65)	(30.64)	(28.02)	n/a	(28.53)
	Stage3	117.81	109.30	101.33	107.82	114.18	112.06
		(33.38)	(31.15)	(33.64)	(31.69)	(31.94)	(32.13)
$H_0{:}\mu_2=\mu_3$							
t-test		1.53	1.46	0.56	0.40	n/a	1.03
P-value		0.13	0.15	0.57	0.69	n/a	0.30
$H_0{:}\sigma_2^2=\sigma_3^2$							
F-test		1.28	1.18	1.21	1.28	n/a	1.27
P-value		0.30	0.47	0.43	0. 30	n/a	0.31

Note: ‡: p<0.01, †: p<0.05 and *: p<0.1 and standard deviation listed in parenthesis

Table XVIII. Comparison of monthly price of FG-gladiolus between stage 2 and 3 (unit: dollars)

		TPAH	CHAH	TNAH	TCAH	KHCH	TOTAL
Mean	**Stage2**	100.90	95.37	92.37	77.05	n/a	130.23
		(21.33)	(21.82)	(21.02)	(17.17)	n/a	(31.08)
	Stage3	94.62	86.15	87.18	70.44	97.07	119.28
		(26.67)	(23.72)	(22.19)	(20.18)	(26.73)	(29.70)
$H_0{:}\mu_2=\mu_3$							
t-test		1.56	2.44	1.45	2.11	n/a	2.18
P-value		0.12	0.02†	0.15	0.04†	n/a	0.03†
$H_0{:}\sigma_2^2=\sigma_3^2$							
F-test		1.56	1.18	1.11	1.38	n/a	1.10
P-value		0.06*	0.48	0.64	0.17	n/a	0.70

Note: ‡: p<0.01, †: p<0.05 and *: p<0.1 and standard deviation listed in parenthesis