Making the Un-transactional Transactional: A Case Study in Foundry Industry

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Abstract – Collaborative commerce has become a competitive weapon in the virtual world. However, there is little empirical evidence on the effect of collaborative commerce in reducing inter-company transaction costs within the Transaction Cost Economy (TCE) theory. This paper analyzes the practical case of company A in the semiconductor foundry industry to reduce un-transactional factors and facilitate transactional commerce. The results indicate that collaborative commerce has a significant impact on reducing monitoring, searching and contracting costs, while playing a more modest role in reducing enforcement costs.

Keywords – **Collaborative Commerce, Foundry, Transaction Cost Economy**

I. INTRODUCTION

In the past 40 years, the global semiconductor industry has experienced a rapid rate of technological change, including rising costs of production, declining prices of final products and increases in vertical specialization [1], which has resulted in the entry of specialized firms into semiconductor design, manufacture, equipment production, and process development. Such firms include the pure-foundry, IC designer, silicon IP vendor, design services provider, design service alliance, value chain aggregator et al.

Collaboration has emerged as a critical business practice for improving performance of the value chain and seeks to electronically synchronize business-to-business and business-to-consumer trading partners. This form of collaboration has come to be known as collaborative commerce (c-commerce) [2] [3]. C-commerce focuses on the cost reduction of business process through seamless application of information and communication technology to complete transactions efficiently[4].

How do firms conduct business with one another without incurring significant transaction costs? In this research, we would like to leverage the framework of the TCE theory to analyze this phenomenon by using a collaborative commerce approach. The research question is framed as "**How can the features of collaborative commerce reduce transaction costs within the TCE theory?**"

II. LITERATURE

Building on the foundational theory of transaction costs that Ronald Coase [5] put forth, Williamson [6] discussed in depth the various transaction costs involved in the firm decision making process behind going to market as opposed to relying on the firm's own resources to produce a product.

Drawing on both organizational and legal theory, Williamson outlines *ex ante* and *ex post* transaction costs [7]. *Ex ante* transaction costs refer to costs that occur prior to the actual transaction. *Ex post* transaction costs occur after the actual transaction has occurred. These costs are broken down into two periods. In the first period, the *ex ante* decisions are based upon the amount of transaction-specific sunk costs. This decision-making process occurs before the actual transaction, allowing decision-makers to consider the consequences of their decision to go to market. *Ex post* decisions, in the second period, refer to production decisions and the distribution of resulting profits. In this period, decision-makers are faced with problems that result after the transaction occurs.

The aggregate value of these costs equate to the total transaction cost involved with the decision to go to market. Dyer [8] identified four subsets of transaction costs which are searching costs, contracting costs, monitoring costs, and enforcement costs.

Prior to the concept of collaborative commerce, firms relied upon enterprise resource planning, supply chain management, and customer relationship management initiatives. Collaborative commerce initiatives use an internet-based technology that promotes collaboration in business to improve inter-firm interactions [8]. The ability for firms to "talk" in a well-defined interface allows the communication of data with a "plug-and-play flexibility."

Transaction costs are reduced by the usage of information technology within the scope of the transaction. This is the role of collaborative commerce described earlier. As a result of different collaborative commerce solutions, firms see a marked reduction of transaction costs.

The research framework serves to map the various collaborative commerce features under four collaboration themes company A experiences, namely general collaboration, design collaboration, engineering collaboration, and logistic collaboration, to the four types of transaction costs: searching cost, contracting cost, monitoring cost and enforcement cost.

III. METHODOLOGY

Case studies allow researchers to look within an issue that would not otherwise be researched thoroughly. It is clear, however, that case studies are highly relevant when it comes to illustrating a particular situation [9]. This allows the researchers to make direct observations and

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engage in a collection of data that would otherwise be impossible under other methods. Through careful observation and engagement in the collection of details, the researchers hope to illuminate the foundry industry through the lens of transaction cost economics.

To maximize the effectiveness of the case, the researchers may employ the method of triangulation to ascertain information. Through triangulating information, the researchers are able to ascertain information not otherwise explicitly stated within a source. The researchers have accrued a substantial amount of knowledge and experience from the development of the collaborative commerce model at the firm as well as the development teams of these collaborative commerce solutions. The researchers incorporate the use of charts, figures, tables, exhibits, and surveys within the scope of this case study. Supplemental information will be drawn from other sources such as software solution providers, standards consortia, and papers and Internet sources.

Through the use of the case study, the researchers address the topic of transaction cost economics.

VI. ANALYSIS AND RESULT

1. System View of Collaborative Commerce Foundry services have a broad range due to the nature of the business engagement between the customers and the foundry service provides, as demonstrated by Company A. Figure 1 depicts the services by company A with respect to the IC life cycle.

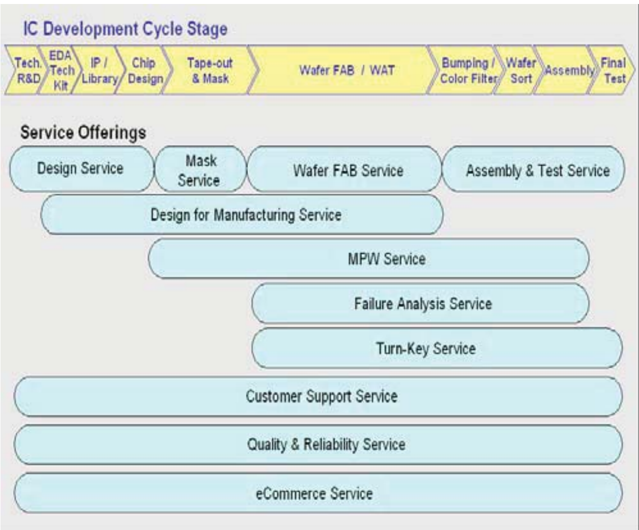

Fig. 1. Foundry services with respect to IC life cycle

From the system function standpoint, company A offers the following 5 solutions: 1) Customer Portal Solution (A-Online), 2) Direct System-to-System Solution (A-Direct), 3) Yield Enhancement System (A-YES), Internet Layout Viewer (A-ILV) and 5) e-JobView (A-eJobView).

Services and Technologies(A-Online): in this area, company A' corporate introduction, high level technology offering, capacity plan, manufacturing sites, product, market/application/segment, customer profile (IDM, fab-less, system company) are disclosed. This information may not be as essential to the existing customers as to new customers who are in the process of engaging with company A in the early stage. Processes on how to engage with company A for new business is also introduced here. The overall services available are mapped out for customers to select wherever they see fit.

Designer's Portal(A-Online): This is the area where customers' product development and design teams receive the information they need to launch a project and continue onto the product development phase. Documents such as PDK (Process Design Kit), SPICE Model, DFM (Design Rule Manual), Technology files (DRC, LVS, etc.) and many others that design and process related documents essential to IC design are categorized and listed in this portal. In addition to listing the various technical documents in an orderly fashion, Company A went one step forward to establish a unique offering called "Bill of Document" (BOD). BOD's concept is to relieve customers' designers from knowing and memorizing all the details in order to select and download all sorts of technical documents before starting their design work and constantly having to remember to check out the latest documents during the whole design life cycle.

Another feature in the Design Portal is the Potential Die Count Advisor (PDCA) and its associated Technology Selector. When a customer of company A is evaluating whether to launch a product development project, it is vital to know the number of die a wafer will produce, as it directly impacts the cost of the product. PDCA assists the customers in determining the potential die count with a series of technical questions.

Customer Services and Satisfaction(A-Online): That feature ensures that customers and the foundry company have multi-point contacts during the whole product life cycle. As a result, it is very important that company A has a solid process and system to capture all the service issues and has a quick way to trigger corrective actions within the company and respond to customers. In the area, FORD 8-D based process is implemented. Customers can file complaints on-line and receive responses electronically. Internally company A has such a structure where issue owners and solution providers have clear division of labor to see issues resolved in a timely manner. Post sales service issues (field return, RMA and end-customer issues) are also included in this.

Production Information(A-Online): On the customer portal, production information is the most frequented area among all in terms of daily visits. Through these years, company A has built a very strong internal IT systems suite, from SFC (Shop Floor Control), MES (Manufacturing Execution System), SCM (Supply

Chain Management), ERP (Enterprise Resource Planning), OM (Order Management) and most importantly, WIP (Work in Process) tracking system. With the strong internal systems foundation, the company is able to provide such feature as Real-Time WIP (query from any browser) up to the second to see where each lot of products are in the manufacturing process. Another novel feature company A offers in this area is the Real Time Lot Handling (RTLH) system. While the Real Time WIP is designed to show where each lot is in real time, the RTLH allows the customers to give lot handling instructions (hold, change part, release and a few others) in real time and expect the system to respond accordingly. With this feature, the customers have full control over the products that are running in their "virtual fab."

Business Transactions(A-Online): This is the area where real system level transactions occur. The first one is the online tape-out system. Tape-Out is the system in which customers finished their product designs and hand the IC design layouts to company A to produce the masks and prepare for the pilot run. Intensive interactions in the system occur during this transaction. Another important feature in this area is the shuttle service. Customers who need to verify whether a design would work at a reasonable cost can share masks with other customers. With company A's special arrangement, these customers would have no way to know who they are sharing the masks with. They would each obtain their share of the masks and wafers to conduct their design verification. Transactions to reserve their spots on the shuttle and to provide all the technical details needed to make the masks are conducted here. Finally, "Customer Test Line" is a useful feature which allows customers to maintain and manage the test lines used in wafer manufacturing.

Quality and Reliability(A-Online): In this area, quality and reliability related guidelines and rules are clearly disclosed to customers. Since there quite a few fabs in company A, the fab standardization reports are important to customers, and the reports are also updated and presented here. Moreover, an advanced e-Reliability model system is available here in the customer portal for customers to conduct reliability modeling work before and after they have come up with their product design.

Direct System-to-system Link (A-Direct): The customers who already have particular ways of operating on a set of internal systems would prefer the information to be fed to their systems via a company-to-company and system-to-system link over the Internet. Oftentimes, this kind of system-to-system link is referred to as B2Bi (Business to Business integration). System-to-system link establishment existed before the Internet gained its popularity. The most famous solution is EDI (Electronic Data Interchange). Although EDI was adopted in the early stage of the foundry industry by company A, the increasing popularity of Internet hindered the future of EDI and gave the opportunity to the FTP-based ad-hoc proprietary "protocols" for data exchange between companies conducting supply chain collaboration.

Engineering Data Analysis (A-YES): Engineering data analysis is a very critical task during wafer manufacturing. The primary purpose is to improve yields, including the fab line yield, probe (CP) yield and Final Test (FT) yield. Yield improvement takes collaboration from both sides to be successful. In the past, it was not easy for the two sides to collaborate. Files and emails were exchanged back-and-forth very frequently. Time lag and mis-communication occurred from time to time. Wrong versions, wrong data, and wrong timing often caused ineffectiveness and frustration. This impacted the yield improvement progress, which in turns impacts customers' time-to-market and time-to-volume. Company A developed the A-YES (Yield Enhancement System) utilizing a powerful engineering database to collect massive amount of process data, CP yield data and FT yield data for various analysis for in-line process improvement, yield analysis and improvement, BKM (Best Known Method) development.

Internet Layout Viewer (A-ILV): IC designers use an EDA tool (Electronic Design Automation) to design the complex IC circuits. Before this, the IC circuit layout needed to be reviewed by a number of people, especially foundry's design service personnel to make sure there are no major issues in terms of violation of manufacturing process design rules. Company A developed an Internet-based Layout Viewer, which can be shared in real time by multiple parties. A rich set of collaborative features are embedded in the system, such as conferencing, online marking, version control, etc. Many customers have benefitted from this Internet Layout Viewer in terms of the shortened product development cycle and time-to-market.

eJobView (A-eJobView): When the layout is finalized, the GDS file and the mask making data need to be "taped out" to the masking making shop. An intermediate step is usually needed before mask can be made. This intermediate step is called "Job View." What is viewed in a "job view" is the mask layout, translated from the IC layout with a lot of "massaging" using Optical algorithm, called OPC (Optical Proximity Correction). In the past, customers needed to fly to company A's premises for the job view on company A's mask shop's proprietary systems. Joint reviewing by the customer and company A's personnel occurs during the JobView. Corrections, if any, are made before the mask is physically made. Any undetected errors would be enormously costly, not only from the mask and wafer waste (cost) standpoint, but also from the cost associated with losing an opportunity to demonstrate a product in a trade show, which may result in huge market share and financial loss. With A-eJobView, all the work can be conducted at customers' premises over the Internet, resulting in cost and time saving, which directly translates to once again, a lower time-to-market.

2. **Functional View of Collaborative Commerce**

In the previous section, company A's collaborative commerce was analyzed from the point of view of systems and features. In this section, the researchers try to analyze company A's collaborative commerce from the semiconductor product life cycle standpoint. In this way, these collaborative commerce features can be organized in a way that would lend themselves to a better grouping for the matrix analysis in the next chapter. Therefore in this section, the features will be grouped into four groups: (1) General Collaboration, (2) Design Collaboration, (3) Engineering Collaboration, and (4) Logistic Collaboration.

(1) General Collaboration: General functions are the functions that are relevant across the entire life cycle of the semiconductor product development, production and after production services. In company A's collaborative commerce portfolio, there are three features listed below.

- Services and Technologies on A-Online
- Customer Services and Satisfactions on A-Online
- Q&R on A-Online

(2) Design Collaboration: Design collaboration refers to the needed collaboration between company A and the customers during a period when the design related work was the majority of the back-end-forth interactions between the two parties. If the project was not properly evaluated due to inadequate, wrong or misleading information from company A, the risk of ultimate failure of the project is very high. As a result, company A put in a lot of effort in this area to assure the collaboration capabilities are strong and robust to support the "1st step" right. The Features are listed below:

- PDCA (Potential Die Count Advisor) on A-Online
- BOD (Bill of Document) on A-Online
- DFM (Design for Manufacturing) on A-Online
- Circuit Layout Viewer on A-ILV

(3) Engineering Collaboration: Engineering collaboration refers to the needed collaboration between company A and the customers during a period when the engineering related work was the majority of the back-end-forth interactions between the two parties. After the product is designed, it will be "taped out" to company A for pilot run. During the pilot run, a lot of engineering activities need to happen between the two parties. After the tape-out, successive yield enhancement work is the focus. The objective of this collaboration is to ensure that the engineering issues are resolved and the product can go into production. The following are the features for engineering collaboration:

- Tape-Out Transactions on A-Online
- Mask Job View on A-eJobView
- Real Time Lot Handling on A-Online
- Remote Yield Analysis on A-YES
- B2Bi—Engineering on A-Direct

(4) Logistic Collaboration: Logistic collaboration refers to the needed collaboration between company A and the customers during a period when the logistic related work was the majority of the back-end-forth interactions between the two parties. After the product is designed and pilot runs with most of the engineering issues are resolved, production starts. In order to run a lean and responsive supply chain, the customers work with company A very closely on PO placement, WIP management, expedite (pull in) and slow down (push out), capacity arrangement (in-house and company A and outsource to sub-cons), shipping, and many other activities. The features for logistic collaboration are listed below:

- Real Time WIP on A-Online
- Product and Mask information on A-Online
- PO and WIP netting on A-Online
- B2Bi – Logistics on A-Direct

3.Cost Reduction Analysis

Four types of transaction costs were discussed in the literature review: searching, contracting , monitoring and enforcement cost. Sixteen collaborative commerce features in four categories, general, design, engineering and logistic collaboration the company A offers, were discussed. In this section, the sixteen features will be analyzed against the four types of transaction costs. In addition to the qualitative analysis, the researchers use (High, Medium, Low) to describe the relevance of each features in terms of its ability to lower each type of transaction cost.

3.1 Searching Cost Reduction

Searching cost refers to the effort a firm makes to gather information about a good or service of interest on the market and research to determine the potential trading partners. The following collaborative commerce features are considered to provide relevant assistance to companies.

A.Services and Technologies(Relevance High): This function provides a foundation for prospective customers to estimate how and when to contract with company A. With this type of insight into the logistical process of the transaction, customers reduce their searching costs due to the decreased amount of information asymmetry.

B.Potential Die Count Advisor (Relevance High):

Because of the PDCA framework, clients have advanced foresight into the feasibility and relevant implementation of new technologies. Because of this, searching costs are reduced.

C. Customer Services and Satisfaction (Relevance Medium):

Because they provide insight into the transaction and reduce information asymmetry, these additions help customers reduce searching costs.

3.2 Contracting Cost Reduction

Contracting cost refers to the cost associated with negotiating and writing a contract. The semiconductor foundry is very unique in that the success of a product development and manufacturing depends highly on the close collaboration of the two parties for design and manufacturing. Some features are listed below to help reduce the cost:

A. Services and Technologies (Relevance Medium): This feature provides a foundation for prospective customers to estimate how and when to contract with company A. With this type of insight into the logistical process of the transaction, customers reduce their contracting costs due to the decreased amount of information asymmetry.

B. Quality & Reliability (Relevance Medium): Q&R framework on A-Online allows the customer foresight into quality control prior to the making and observation of a contract. This, hereby, lowers contracting costs because customers receive the information they need with respect to the firm being able to provide timely and accurate Q&R information.

C. Potential Die Count Advisor (Relevance Medium): For each generation of technologies, customer may choose to contract with company A for an arrangement unique to that particular technology. PDCA could easily be part of the aid to the contracting process, especially for returning customers.

D. Design for Manufacturing (Relevance Medium): DFM is becoming more and more critical for advanced technologies. So, it is often referenced in the contracting process. Because of its insight into the manufacturing process through design insights, the engineering rules that customers extrapolate helps mitigate contracting costs.

3.2 Monitoring Cost Reduction

A. Real Time WIP (Relevance High): Allows customers to actively monitor the "work in process" aspect of the manufacturing process. The high degree of monitoring capability drastically reduces monitoring costs and allows customers real-time access to the progress of fulfilling the contractual agreement.

B. Real Time Lot Handling (Relevance High): This feature allows customers to issue handling instructions: to hold, release, or revise portions of the manufacturing process. Customers experience a high level of monitoring cost reduction.

C.B2Bi-Logistics (Relevance High): B2Bi allows customers access to a full set of logistical collaboration. Customers bring about dramatic reductions in monitoring costs.

D.PO and WIP netting (Relevance High): This feature allows customers insight into how their PO's work with the WIP running. This reduces the monitoring cost to the customer, as this critical information is provided in a timely fashion.

E. Product and Mask Information (Relevance High): This feature reduces monitoring costs because it provides customers access to wafer product and mask information.

F.B2Bi-Engineering (Relevance High): B2Bi Engineering is a foundation for customers to monitor technical engineering information that is relevant in maximizing the effectiveness of their product development and production. It effectively reduces monitoring costs.

G. Customer Services and Satisfactions (Relevance High): This feature proactively allows customers to file complaints and track resolution progress.

H. Quality & Reliability (Relevance High): Quality and reliability are critical in the manufacture of products for customers. In helping customers monitor these factors, it reduces monitoring costs for the customer.

I. Circuit Layout Viewer (Relevance Medium): Given that it is critical to ensure the tape-out process is monitored, the Circuit Layout Viewer allows two sides to jointly review what is being manufactured. This serves to reduce monitoring costs.

J. Remote Yield Analysis (Relevance Medium): Because this provides insight into how customers' products will be yielding (both now, and in the future) customers and the Firm can jointly improve yields.

K. Mask Job View (Relevance Medium): This is similar to the Circuit Layout Viewer in that it allows the customer and the Firm to view the mask. Customers have the opportunity to see what will be made, ensuring a mask that is consistent with their IC design specifications.

3.4 Enforcement Cost Reduction

Enforcement cost refers to the cost associated with a firm's effort to sanction a transaction partner that has not performed according to the contract. Unlike other transaction costs, enforcement cost only occurs when "bad" things happen. The following feature can be of help.

A. Customer Services and Satisfactions (Relevance Medium): Customer Services and Satisfactions allow the customer to reduce its enforcement costs because this platform allows the customer to issue complaints and view resolutions. This reduces the enforcement cost and allows the customer to assert problems before cost-intensive enforcement (legal) need be applied.

V. DISCUSSION AND CONCLUSION

Table 1 illustrate the level of transaction costs with respect to the types of collaborative commerce solutions. The "y-axis" illustrates the collaborative commerce solutions broken down by types of collaboration: Logistic, General, Design, and Engineering. The "x-axis" illustrates the types of transaction costs: searching costs, contracting costs, monitoring costs, and enforcement costs.

Table 1: Cost Reduction Matrix

		Searching	Contracting	Monitoring	Enforcement
General	Services and Technologies	High	Medium	Medium	Low
	Customer Services and Satisfactions	Medium	Low	High	Medium
	Quality and Reliability	Medium	Medium	Medium	Low
Design	Bill of Document	Medium	Medium	Low	Low
	Potential Die Count Advisor	High	Medium	Low	Low
	Design for Manufacturing	Medium	Medium	Low	Low
	Circuit Layout Viewer	Low	Low	Medium	Low
Engineering	Tape-Out Transaction	Medium	Low	Low	Low
	Mask Job View	Low	Low	Low	Low
	Real Time Lot Handling	Medium	Low	High	Low
	Remote Yield Analysis	Low	Low	Medium	Low
	B2Bi-Engineering	Low	Low	High	Low
Logistic	Real Time WIP	Low	Low	High	Low
	Product and Mask Information	Medium	Low	High	Low
	PO and WIP Netting	Medium	Low	High	Low
	B2Bi-Logistics	Low	Low	High	Low

Company A has rich set of collaborative commerce functions. Many of these functions have a positive impact on the reduction of transaction costs. The most prominent area is the monitoring cost reduction. This probably should not come as a surprise. In the TCE theorems, two major characteristics of the behavioral risks are 1) bounded rationality and 2) opportunism. Opportunism goes hand-in-hand with the information asymmetry [10]. Company A made a great deal of effort in the ability to make itself as transparent as possible to its customers, especially during the production (execution) phase, which in turn helps to substantially reduce monitoring cost. The second prominent area is the searching cost reduction. Searching cost, by nature, also has a lot to do with information provisioning. Company A's effort to organize and provide information for customers in terms of helping them understand the foundry as well as company A is quite significant in the customer's outsourcing decision-making process. Regarding the contracting cost reduction, the relevance of these collaborative commerce features is not as prominent as the former to transaction cost. Contracting is more relevant to spelling out the roles and responsibilities of both sides.

For interactions as complex as those faced by semiconductor transaction partners, it is not easy to completely spell out the R&R in the contract. Some of them depend on special situations and individual companies' preferences. As a result, the information technology and business process oriented collaborative commerce do not have significant relevance in this. Lastly, regarding enforcement cost reduction, collaborative commerce features have little impact. Once again, enforcement costs mostly deal with the situation when one party does not comply to what the contract asserts, or the obligations based on commonly accepted business practices. Therefore the relevance of collaborative commerce is the lowest among all transaction costs.

In summary, to answer the research question of "How can Collaborative Commerce reduce transaction costs within the TCE theory?" The answer is that collaborative commerce has a significant impact on monitoring cost reduction. It also helps reduce the cost of searching and contracting. With respect to enforcement cost reduction, collaborative commerce plays a relatively weaker role. The total cost reduction of collaborative commerce effectively reduces un-transactional factors to facilitate transactional commerce.

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