# A Two-Stage Value Chain Model for Vegetable Marketing Chain Efficiency Evaluation: A Transaction Cost Approach

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## 1 Introduction

China claims to be the most important vegetable producer in the world today, supplying more than half of the total vegetable production (FAO, 2001). With the increasing the concerns of improving farmers' welfare, vegetable sector has increasingly drawn the attention of policy makers and scholars. Vegetable producers in Nanjing City, P.R. China have a choice between different marketing outlets for selling their products. Their produce can be sold with a stall or delivered to traders at the wet market, or marketed through the local wholesale market. Farmers can choose to sell the whole harvest or a share of their produce through any one of these outlets. Delivery conditions and quality demands tend to differ widely amongst these outlets, occasioning various types of transaction costs and offering farmers different implicit incentives for adjustment of their production and marketing systems (Lu, 2003, Ruben, et al., 2006).

The presence of transaction costs in local markets implies that the efficiency of transactions is seriously constrained. Reduction of the transaction costs might encourage farmers towards resource intensification while increasing their family income (Ruben, et al., 2006). Moreover, within an open market environment, any reduction in transaction costs could be envisaged as a useful device for enhancing productivity and quality that could eventually lead to higher farmers' income as well as better resource management practices (North, 1990).

Vegetable supply chains in the Nanjing area offer a particularly challenging setting for the analysis of the importance of transaction costs for production and supply chain efficiency analysis. Three co-existing market outlets offer competing conditions, with local markets where farmers directly provide fresh products to rural villages, (semi) urban consumers as an important retail outlet served by local traders, and wholesalers that serve as a clearing house between surplus and deficit regions.

The objective of this paper is to evaluate the technical efficiency (TE) for vegetable producers' multiple chain alternatives regarding to their production techniques, resource endowments and institutional combinations; and to investigate the impact of disaggregated different categories of transaction costs on marketing chain efficiency. A two-stage value chain model was applied (Sexton and Lewis, 2003). Data collected from 84 vegetable (tomatoes as example) producers offer the basis for the analysis.

The remainder of paper is divided into three sections. Section 2 introduces the theoretical perspectives and methodologies used in this research. In Section 3, the research area and empirical results are shown. We conclude with discussions in Section 4. We indicate several limitations of this research which pave the way for further research.

## 2 Theoretical perspectives and methodologies

### *2.1 Two-stage value chain model formulation*

Data Envelopment Analysis (DEA), origin from Farrell (1957), is a linear programming-based methodology for evaluating the relative efficiency of each member of a set of organizational units (Charnes, et al., 1978). The units, called *decision-making units* (DMUs), consume various levels of each specified input and produce various levels of each specified output. DEA evaluates the efficiency of a DMU relative to an empirical production possibility frontier determined by all DMUs under appropriate assumptions regarding returns to scale and orientation.

DEA was initiated by Charnes, Cooper, and Rhodes (1978) with assumptions of constant returns to scale in the production process. Banker, Charnes, and Cooper (1984) later proposed an alternative model that can handle more flexible cases of variable returns to scale. Following Sexton and Lewis (2003), we extend the classical DEA model to two-stage model. Please refer to Figure 1. The first Sub-DMU consumes inputs $x_i$ to produce *intermediate products* $z_d$. These, in turn, are the inputs to the second Sub-DMU, which are used to produce the DMU's final outputs $y_r$. The advantage of the two-stage value chain model is capable to evaluate the relative efficiencies of each DMU and each of its sub-DMUs in a value chain.

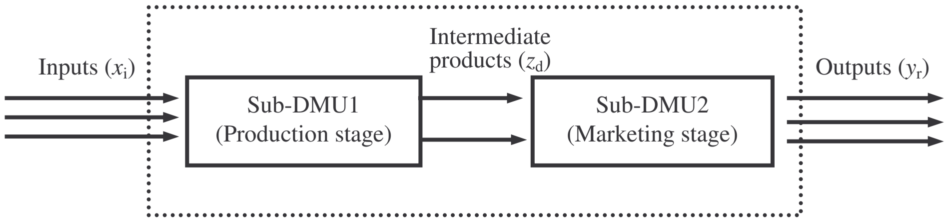

*Figure 1 Two-stage value chain model*

In a two–stage value chain model, we treated the vegetable marketing chain as a production and marketing operations. We envision the vegetable producers as the DMUs, with production stage as sub-DMU1 and marketing stage as suc-DMU2. In the first stage, producers use farmland, fixed inputs and managerial inputs to produce certain quantity of vegetables (intermediate products), then at the second stage, these vegetables will be sold at the market place to gain income. The contribution of the transaction costs to the vegetable supply chain technical efficiency both at production and marketing stages will be examined by using Tobit model (McCarty and Yaisawarng, 1993, Wand and Schmidt, 2002). The vegetable marketing chain may be inefficient at either stage, or at both stages. However, the managerial remedies for such inefficiency will be different within each stage, and thus it is crucial for us to identify the extent of such inefficiency within each stage.

We will present the two-stage value chain model using an output orientation and assuming variable returns to scale. Sexton and Lewis (2003) showed the simple sample in which each DMU consumes one input, produces and consumes one intermediate product, and produces one output. In Figure 2, two points represent each sub-DMU. In the left-hand quadrant, DMU *k* at the point ($X_k$, $Y_k$), where $X_k$ is the level of the input consumed by DMU *k*'s stage 1 sub-DMU and $Y_k$ is the level of the intermediate product produced by its stage 1 sub-DMU. Note that the input axis increases toward the left. In the right-hand quadrant, we plot DMU *k* at the point ($Y_k$, $Z_k$), where $Z_k$ is the level of the output produced by DMU *k*'s stage 2 sub-DMU.

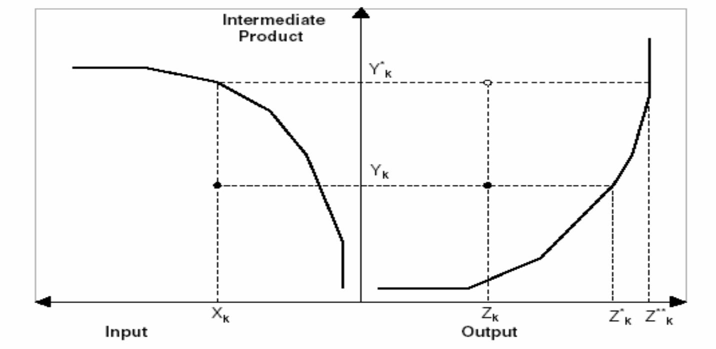

*Figure 2 The simplest output-oriented two-stage value chain model scenario*

The piecewise linear structure shown in the left-hand quadrant of Figure 2 represents the DEA production frontier established by the stage 1 sub-DMUs under an appropriate returns to scale specification. Similarly, the piecewise linear structure shown in the right-hand quadrant of Figure 2 represents the DEA production frontier established by the stage 2 sub-DMUs under an appropriate returns to scale specification, which may differ from that used in stage 1. Under DEA assumptions, the stage 1 sub-DMU at DMU *k* could have increased its production of the intermediate product to level $Y_k^*$, and its inverse efficiency score is computed as:

$$\theta_{1k} = \frac{1}{E_{1k}} = \frac{Y_k^*}{Y_k}$$

Similarly, given the actual performance of the stage 1 sub-DMU at DMU *k*, the stage 2 sub-DMU at DMU *k* could have increased its production of the output to level $Z_k^*$, and its inverse efficiency score is computed as:

$$\theta_{2k} = \frac{1}{E_{2k}} = \frac{Y_k^*}{Y_k}$$

Suppose that the stage 1 sub-DMU at DMU *k* had been efficient and had produced $Y_k^*$ of the intermediate product. Then the stage 2 sub-DMU at DMU *k* would have produced $Z_k^{**}$ of the output if it were efficient. Therefore, using an input level $X_k$, an efficient DMU *k* would have produced output level $Z_k^{**}$, and DMU *k*'s organizational inverse efficiency under an output orientation is computed as:

$$\theta_k = \frac{1}{E_k} = \frac{Z_k^{**}}{Z_k}$$

Thus, to solve the two-stage value chain model for DMU *k* using both an output orientation and variable returns to scale in each stage, we formulate and solve three DEA problems. For $d = 1,\ldots, D$, we let

$X_{di}$ =Level of input *i* consumed by DMU *d*, for i =1,…, *I*;

$Y_{dp}$ =Level of intermediate product *p* produced and consumed by DMU *d*, for *p* =1,…, *P*;

$Z_{dr}$ =Level of output *r* produced by DMU *d* for *r* =1,…, *R*;

$\lambda_{dk}$ =Weight placed on the Stage 1 sub-DMU at DMU *d* by the stage 1 sub-DMU at DMU *k*;

$\mu_{dk}$ =Weight placed on the Stage 2 sub-DMU at DMU *d* by the stage 2 sub-DMU at DMU *k*.

For the stage 1 sub-DMU at DMU *k*, we solve:

$$
\begin{aligned}
& Max \;\; \theta_{1k} \\
& subject \quad to \\
& \sum_{d=1}^{D} \lambda_{dk} X_{di} \leq X_{ki}; \qquad i = 1 \ldots\ldots I \\
& \sum_{d=1}^{D} \lambda_{dk} Y_{dp} - \theta_{1k} Y_{kp} \geq 0; \qquad p = 1 \ldots\ldots P \\
& \sum_{d=1}^{D} \lambda_{dk} = 1 \\
& \lambda_{dk} \geq 0; \qquad d = 1 \ldots\ldots D \\
& \theta_{1k} \geq 0
\end{aligned}
$$

And for the stage 2 sub-DMU at DMU *k*, we solve

$$
\begin{aligned}
& Max \;\; \theta_{2k} \\
& subject \quad to \\
& \sum_{d=1}^{D} \mu_{dk} Y_{dp} \leq Y_{kp}; \qquad p = 1 \ldots\ldots P \\
& \sum_{d=1}^{D} \mu_{dk} Z_{dr} - \theta_{2k} Z_{kr} \geq 0; \qquad r = 1 \ldots\ldots R \\
& \sum_{d=1}^{D} \mu_{dk} = 1 \\
& \mu_{dk} \geq 0; \qquad d = 1 \ldots\ldots D \\
& \theta_{2k} \geq 0
\end{aligned}
$$

### *2.2 Model impact of transaction costs on technical efficiency*

In order to examine the impact of transaction costs on TE both at the production and marketing process as well as the chain level, we carry on the study by regressing the scores of TE, derived from DEA, against their respective different type of transaction costs. Nevertheless, some vegetable producers that are, relatively speaking, the most efficient in comparison with the others are employed to construct the nonparametric production frontier. Hence, they have perfect scores of one for their efficiency measurement.

McCarty and Yaisawarng (1993) suggest that, under this circumstance, the Tobit regression model should be used, because it can account for the censoring of the dependent variable. When the dependent variable is censored, values in a certain range (>1) are transformed to a particular value (one). If, for firm *i*, we represent the original scores of technical efficiency as $TE_i^*$ the measured (censored) scores of technical efficiency by DEA as $TE_i$, and transaction costs as $I_i$, then the Tobit regression model is formulated as:

$$\begin{aligned} &TE_i^* = \alpha_0 + \alpha_I I_i + \varepsilon_i, \\ &TE_i = 1, \quad if \quad TE_i^* \geq 1, \\ &TE_i = TE_i^*, \quad if \quad TE_i^* < 1, \quad i = 1,\ldots, n. \end{aligned}$$

When the coefficient estimate $a_I$ for transaction costs is found to be significantly positive, we are provided with statistical evidence to corroborate that transaction costs exerts a positive total effect on the farm household's technical efficiency in certain stage.

## 3 Empirical Results

### *3.1 Vegetable production and marketing in Nanjing area*

Vegetable production in Nanjing experienced a strong growth during recent years. Between 1998 and 2003, the cultivated area under vegetables represents an annual growth rate of 27%. Vegetable production reached 3,770 million tons in 2003 and output value was 3,425 million yuan[1], both accounts for a 20% annual growth rate.

After a long period of market development and with the liberalization of marketing system, Nanjing vegetable markets became far more competitive. Nowadays, the vegetable marketing system includes large-scale wholesale markets, retail markets (mainly wet markets), and local and foreigner supermarkets.

We collected data from a random sample of 86 farm households in *Maqun* Township, located in east part of Nanjing City. The farmers rely on three different marketing channels selling their vegetables: Direct sales to consumers, trough a stall at the wet market (N=46); Sales transactions with traders that purchase the produce at the stall and deliver to local institutions (N=20); Delivery to the local wholesale market (N=20).

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[1] 1US$=8.04 yuan (March 27, 2006).

### *3.2 Define input, intermediate products and outputs*

We conceive of a vegetable producer as a two-stage production and marketing activities. The producers use resources (farmland, fixed input and managerial input) to acquire intermediate product: vegetables. Then, vegetables were sold in market and farmers get income. We assume that each farmer's initial focus is on producing enough vegetable to try to get more income. We therefore construct our DEA model with only one output: the total value of the vegetables.

A producer earn more income from marketing by achieve a high yield of vegetables from certain farmland. So farmer's objective at the production stage is output maximization. We identify three inputs to the production stage: farm land, fixed inputs (shelf, transportation vehicle) and managerial inputs (knowledge and experience). Vegetables are the output of the first stage, they are intermediate products in my model. The income from the market is the final output for the vegetable value chain.

The statistical results of the inputs, intermediate output and final output of this research are listed in Table 1.

*Table 1 Statistical descriptions of valuables used in the analysis for all chains*

| Marketing Chains | Total | Direct sales chain | Sell to trader chain | Sell to wholesaler chain |
|---|---|---|---|---|
| Vegetable area (1/15 *ha*) | 0.70<br>(0.78) | 0.66<br>(0.53) | 0.71<br>(0.60) | 0.78<br>(1.31) |
| Year of vegetable production (year) | 18.5<br>(7.6) | 18.8<br>(7.4) | 19.9<br>(8.5) | 16.5<br>(7.0) |
| Value of fixed input (yuan) | 3282.4<br>(4350.4) | 2384.0<br>(2504.6) | 3835.0<br>(3267.0) | 4796.0<br>(7379.0) |
| Volume of vegetable (yuan) | 4105.5<br>(4033.6) | 3939.6<br>(3564.6) | 4635.0<br>(4417.6) | 3957.5<br>(4774.2) |
| Marketing value of vegetable (yuan) | 2173.3<br>(1925.2) | 2317.1<br>(1958.2) | 2502.0<br>(2084.8) | 1513.5<br>(1591.1) |

*Note: Standard deviations are in parentheses.*

*Source: Nanjing vegetable marketing survey, 2002.*

### *3.3 Chain technical efficiency results*

Table 2 showed the results of the DEA and Two-stage value chain model. The results confirm the findings of Lu (2003) and Ruben, Lu and Kuiper (2006) that vegetable supply chains in Nanjing area are less efficiency in general (74%). Technical efficiency differ both at channel level and stage level.

*Table 2 Chain technical efficiency scores of production and marketing stages for all chains*

| Marketing Chains | Total TE | Production stage TE | Marketing stage TE |
|---|---|---|---|
| Direct sales chain | 0.673<br>(0.24) | 0.974<br>(0.07) | 0.542<br>(0.23) |
| Sell to trader chain | 0.801<br>(0.28) | 0.987<br>(0.03) | 0.697<br>(0.27) |
| Sell to wholesaler chain | 0.847<br>(0.22) | 0.976<br>(0.08) | 0.696<br>(0.23) |
| Total | 0.743<br>(0.25) | 0.978<br>(0.06) | 0.614<br>(0.250) |

*Note: Standard deviations are in parentheses.*
*Source: Nanjing vegetable marketing survey, 2002.*

Results showed that the directing marketing is the least efficient chain, followed by the chain of sell to trader at the wet market. While the wholesale market chain has the highest chain efficiency level among the three co-exist chains. Efficiency scores are 67.3%, 80.1% and 84.5% for three chains respectively. Two-stage value chain model infers vegetable producers in Nanjing area doing much better for the production than marketing. Three outlets have nearly the same high efficiency scores (98%) at the production stage, but much less efficient (less than 70%) at the marketing stage and rather differ amongst the chains. Again direct sales chain shows least efficient (54.2%) while sale to trader at the wet market and at the wholesale market have nearly the same efficient level of 70%. This indicates the opportunities to improve the income lie in the marketing perspectives rather than production for Nanjing vegetable producers. The higher market price at the wet market can not compensate the value loss incurred by the high level of transaction costs. Results indicate the vegetable producers should pursue the low transaction costs marketing chains rather than ask for a higher market price.

### *3.4 Transaction costs on chain technical efficiency*

We used a composite of various indicators to disentangle the effects of different components of transaction costs on the technical efficiency of vegetable supply chains and production and marketing stages. Transferring the concept of transaction costs to the operational domain remains elusive (Grover and Malhotra, 2003). Several authors showed their creative capacity to evaluate the transaction costs in different area. Following common practices (Escobal, 2005, Hobbs, 1997), we decompose four categories of the transaction costs in this research: a) Transportation Costs, depending on distance, time, road conditions and availability of own means of transport; b) Information costs, depending on the number of traders visited before selling and the sources of access to market information; c) Negotiation costs, related to the number of visits for reaching an agreed price; and d) Monitoring costs, related to the number of years the farmer is engaged with the trader. Table 3 showed the impacts of transaction costs on technical efficiency for all samples in the research area.

*Table 3 Impacts of transaction costs on technical efficiency for total samples*

| | Total TE | Production stage TE | Marketing stage TE |
|---|---|---|---|
| Information costs | -0.64*** | -0.45*** | -0.79*** |
| | (0.20) | (0.07) | (0.29) |
| Negotiation costs | -0.02*** | -0.01*** | -0.03*** |
| | (0.01) | (0.00) | (0.01) |
| Monitoring costs | 0.03 | -0.12** | 0.10 |
| | (0.17) | (0.06) | (0.24) |
| Transportation costs | -0.01*** | -0.01*** | -0.01*** |
| | (0.00) | (0.00) | (0.00) |

*Note: *: significant at 10% level; ** significant at 5% level; ***: significant at 1% level; Standard errors are in parentheses.*

The transaction costs generally have a significant negative impact on chain technical efficiency for vegetable supply chains. This means that vegetable producers can reach a more effective production and marketing solutions if they can reduce the transaction costs incurred in their either production or marketing activities. The only exception we found is the negotiation costs, which positively influence technical efficiency for marketing stage. This may because of the indicator of negotiation cost in this study is the relationship between vegetable producers and their traders. Normally, the longer relationship, the more trust between them, which lead to a low level of monitoring costs.

The impacts of transaction costs on technical efficiency for specified chains at both stages are showed in Table 4. Results indicated that three vegetable supply chains have different efficiency level under the occurrence of transaction costs.

*Table 4 Impacts of transaction costs on technical efficiency for all chains*

| | Direct sales | | Sell to trader | | Sell to wholesaler | |
|---|---|---|---|---|---|---|
| | production stage TE | marketing stage TE | production stage TE | marketing stage TE | production stage TE | marketing stage TE |
| Information cost | -0.38***<br>(0.10) | -0.63<br>(0.40) | -0.64**<br>(0.29) | -1.23<br>(2.02) | -0.47***<br>(0.11) | -0.52<br>(0.32) |
| Negotiation cost | -0.01***<br>(0.00) | -0.03**<br>(0.02) | -0.01***<br>(0.00) | -0.02<br>(0.02) | -0.004<br>(0.01) | -0.04***<br>(0.01) |
| Monitoring cost | - | - | 0.11**<br>(0.05) | 0.05<br>(0.35) | -0.04<br>(0.10) | 0.24<br>(0.29) |
| Transportation cost | -0.01***<br>(0.00) | -0.006<br>(0.006) | -0.01**<br>(0.00) | -0.03**<br>(0.02) | -0.03***<br>(0.00) | -0.02<br>(0.01) |

*Note: *** significant at 1% level; **: significant at 5% level; *: significant at 10% level. Standard errors are in parentheses.*

Excluding the monitoring costs, all transaction costs significantly decrease the technical efficiency level for all three chains at production stage. This means that the farmers have more opportunities to improve their production performance if they can reduce transaction costs. It is not surprised for the positive effect of monitoring costs to technical efficiency score since the indicator of the monitoring costs in this research is relationship duration, which is helpful to decrease the monitoring costs.

At marketing stage, Negotiation costs and transportation costs are more important to technical efficiency than the other costs. Negotiation costs have a significant negative impact on direct sales chain and sell to wholesaler chain. If farmers can reduce the number of visits before they can reach agreed price with traders, they will gain more income. Transportation costs are very important to sell to trader chain. It implies that the road condition and distance to the market place are crucial for farmers to increase their income. In addition, the own of transportation means is also important for vegetable farmers.

## 4 Discussions and conclusions

We applied two-stage value chain model in this study to show how to use DEA methods to look inside the decision making process. The two stages with the outputs of the first stage becoming the inputs to the second stage allow us have a greater insight as to the locations of organizational inefficiency. Thus, the Two-Stage value chain model can be applied in many managerial contexts (Sexton and Lewis, 2003).

By applying two-stage value chain model to vegetable supply chain, we evaluated the efficiency level both at the vegetable production and marketing stages. This analysis gives a good opportunity for the vegetable producers to seeking the efficient stage to achieve higher yields or get more income. Meanwhile, this analysis also gives an opportunity for managers to design effective and efficiency chains via enhancing the weak points throughout the chain. Tobit technology used to model the contribution of the transaction costs involved in the vegetable supply chain which offers a way, from transaction costs point of view, to improve technical efficiency at particular stage in the supply chains.

Empirical study of vegetable supply chain showed that transaction costs have a significant influence to the chain efficiency of supply chains in Nanjing area in general. Transaction costs showed different impacts on different marketing chains. Direct sales chain incurs the highest transaction costs and results the lowest efficiency level in specific. At sub stage level, vegetable production function more efficiently than marketing activities. So the management attention should be paid to knowledge the vegetable producers' market experiences and market information, such as where and how to sell their products, how to reduce costs during marketing, etc.

## 5 Limitations for further research

Since the transaction costs are not the direct inputs of the vegetable production and marketing activities, the difficulties of capture the transaction costs in supply chain, as well as the choice of the transaction costs indicators influence the final results of the Tobit regression. The transaction cost approach gives us more opportunities to improve the analysis results on the one hand; we also face more challenge to determine the proper indicators on the other hand.

We only have limited samples and unequally distributed to three chains, this may lead to a biased technical efficiency results (Staat, 2001, Zhang and Bartels, 1998). Generally, the smaller the sample size, the higher the efficiency score. Also due to the limitation of the data sources, we did not include any important quality adjustments for land, such as fertilizer, access to irrigation, etc. Thus the results of this research should be interpreted with caution.

In addition, we only consider two stages in the vegetable supply chain in this research. This definition of value chain is not possible to include all types of marketing chains in practice. Multiple stages supply chains may be more reasonable. Thus our two-stage value chain model showed less capacity to evaluate the technical efficiency for such supply chains. Fortunately, Zhu (2002) developed a value chain model which is valid for multiple stages supply chains which can be applied to our research area for a comprehensive analysis for further research.

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