RGC Ref. No.:
UGC/FDS15/E02/21
(please insert ref. above)

RESEARCH GRANTS COUNCIL
COMPETITIVE RESEARCH FUNDING SCHEMES FOR
THE LOCAL SELF-FINANCING DEGREE SECTOR

FACULTY DEVELOPMENT SCHEME (FDS)

Completion Report
(for completed projects only)

Submission Deadlines:
1. *Auditor's report with unspent balance, if any: within **six** months of the approved project completion date.*
2. *Completion report: within **12** months of the approved project completion date.*

Part A: The Project and Investigator(s)

1. Project Title

A Unifying Framework for Structural Efficiency Measurement: Theories and Applications

2. Investigator(s) and Academic Department(s) / Unit(s) Involved

Research Team	Name / Post	Unit / Department / Institution
Principal Investigator	Dr LEE Shu-kam / Associate Professor	Department of Economics and Finance, Hong Kong Shue Yan University
Co-Investigator(s)	Prof LI Sung-ko / Senior Research Fellow	Department of Economics and Finance, Hong Kong Shue Yan University
Co-Investigator(s)	Dr WOO Kai-yin / Associate Professor	Department of Economics and Finance, Hong Kong Shue Yan University
Co-Investigator(s)	Dr. SHUM Paul Kwok-ching / Assistant Professor	Rita Tong Liu School of Business and Hospitality Management, Saint Francis University

3. Project Duration

	Original	Revised	Date of RGC / Institution Approval *(must be quoted)*
Project Start Date	01/01/2022	N/A	N/A

Project Completion Date	31/12/2023	N/A	N/A
Duration *(in month)*	24	N/A	N/A
Deadline for Submission of Completion Report	31/12/2024	N/A	N/A

4.4 Please attach photo(s) of acknowledgement of RGC-funded facilities / equipment.

N/A

Part B: The Final Report

5. Project Objectives

5.1 Objectives as per original application

1. To develop a set of new models of structural efficiency with subgroups

2. To develop a unifying framework for measuring structural efficiency

3. To apply the new models to identify potential problems in real-world cases

5.2 Revised objectives

Date of approval from the RGC: N/A

Reasons for the change:

1.

2.

3. ....

5.3 Realisation of the objectives
(Maximum 1 page; please state how and to what extent the project objectives have been achieved; give reasons for under-achievements and outline attempts to overcome problems, if any)

Efficiency is key leverage for sustaining the profitability of individual firms and industry, and in managing resource allocation within and across economic regions. The term "efficiency" represents the current performance of a production unit compared to the best that production unit can perform. The term "inefficiency" means a production unit is not performing at the best that it can perform. Industry applications of the current literature focus mainly on individual efficiency, not the efficiency of the whole group. This proposed project, therefore, aims to develop a unified framework for measuring group efficiency (structural efficiency) under different assumptions.

We improved upon the current structural efficiency measurement in two directions:
1. A set of "S-shaped" production technology which do not require convex assumptions
2. A set of models of structural efficiency under different assumptions

Researchers could select the appropriate production technology and model within this unifying framework which meets with their research needs or theoretical beliefs to measure individual or group efficiency.

The developed framework is then applied to different real-world cases, including Hong Kong public hospital sector, Chinese regional economy, Companies listed in Hong Kong and China stock market, US manufacturing industry. Implications on unit's internal management and resource allocation among units were provided.

5.4 Summary of objectives addressed to date

Objectives *(as per 5.1/5.2 above)*	**Addressed** *(please tick)*	**Percentage Achieved** *(please estimate)*
1. To develop a set of new models of structural efficiency with subgroups	V	100%
2. To develop a unifying framework for measuring structural efficiency	V	100%
3. To apply the new models to identify potential problems in real-world cases	V	100%

6. Research Outcome

6.1 Major findings and research outcome
(Maximum 1 page; please make reference to Part C where necessary)

The project aims to develop a unified framework for measuring group efficiency (structural efficiency) under different assumptions.

A set of new models of structural efficiency with subgroups under different assumptions was developed (Objective 1). We developed two new models for "S-shaped" production technology for single output under partially convex assumption (Li et al. 2024a) and multiple outputs under nonconvex assumption (Li et al. 2024b). An input-oriented structural efficiency which assumes total outputs are fixed was introduced in Tsang et al. (2024a). A revenue structural efficiency model which allows for heterogeneous subgroup technology and prices was introduced in Tsang et al. (2024b). A structural efficiency model which allows the existence of fixed input was introduced in Li et al. (2024c).

The abovementioned models compose a unifying framework of structural efficiency (Objective 2). Researchers could select the appropriate production technology and model within this unifying framework which meets with their research needs or theoretical beliefs to measure individual or group efficiency. For example, Tsang et al. (2024b) showed that heterogeneous subgroup technology and heterogeneous subgroup prices can be combined into a single model. On the other hand, Li et al. (2024c) showed the partially convex assumption and nonconvex assumption are not applicable for the model allowing the existence of fixed input which requires convex technology. Other combinations of models within the unifying framework can be found in the articles mentioned above as special cases under different assumptions.

Finally, the new framework was applied to different real-world cases to identify potential problems (Objective 3). For example, Cheng et al. (2023) applied the new framework to study resource deployment efficiency for ESG. Li et al. (2023) applied the new framework to selecting variables in studying China listed companies. Tsang et al. (2024c) applied the new framework to estimating the potential gain of the economic integration of the Guangdong-Hong Kong-Macao Greater Bay Area. Additionally, application on Hong Kong public hospital sector, Chinese regional economy, Companies listed in Hong Kong and China stock market, US manufacturing industry, can be found in the articles mentioned above as illustrations.

6.2 Potential for further development of the research and the proposed course of action
(Maximum half a page)

There are 3 papers not yet published in this project. The project team plans to further modify them based on the previous submission comments and resubmit them in the near future.

The models developed in this project should have potential to apply to other cases. The project team plans to further generate a few more papers by applying these models.

One direction of potential further development of this project is to include "bad" outputs (e.g., pollution). Under the existence of undesirable outputs, the unifying framework should be more capable of evaluating the fast-developing studies of ESG or sustainable development.

7. Layman's Summary

(Describe in layman's language the nature, significance and value of the research project, in no more than 200 words)

Efficiency is a key leverage for sustaining the profitability of individual firms and industry, and in managing resource allocation within and across economic regions. The term "efficiency" represents the current performance of a production unit compared to the best that production unit can perform. The term "inefficiency" means a production unit is not performing at the best that it can perform. Industry applications of the current literature focus mainly on individual efficiency, not the efficiency of the whole group. This proposed project, therefore, aims to develop a unified framework for measuring group efficiency (structural efficiency) under different assumptions.

This project improved upon the current structural efficiency measurement in two directions: (1) A set of "S-shaped" production technology which do not require convex assumptions; (2) A set of models of structural efficiency under different assumptions. Researchers could select the appropriate production technology and model within this unifying framework which meet with their research needs or theoretical beliefs to measure individual or group efficiency. The developed framework is then applied to different real-world cases, including Hong Kong public hospital sector, Chinese regional economy, Companies listed in Hong Kong and China stock market, US manufacturing industry. Implications on unit's internal management and resource allocation among units were provided.

Part C: Research Output

8. Peer-Reviewed Journal Publication(s) Arising Directly From This Research Project

(Please attach a copy of the publication and/or the letter of acceptance if not yet submitted in the previous progress report(s). All listed publications must acknowledge RGC's funding support by quoting the specific grant reference.)

The Latest Status of Publications				**Author(s)** *(denote the corresponding author with an asterisk*)*	**Title and Journal / Book** *(with the volume, pages and other necessary publishing details specified)*	**Submitted to RGC** *(indicate the year ending of the relevant progress report)*	**Attached to this Report** *(Yes or No)*	**Acknowledged the Support of RGC** *(Yes or No)*	**Accessible from the Institutional Repository** *(Yes or No)*
Year of Publication	**Year of Acceptance** *(For paper accepted but not yet published)*	**Under Review**	**Under Preparation** *(optional)*						
2023				Li, S.K.*, Tsang, C.K., Lee, S.K.	Selecting Proxies for Inputs with Limited Data in Data Envelopment Analysis, International Journal of Advances in Electronics and Computer Science, 10(10), 21-27.	Yes Appendix 1	Yes	Yes	Yes
2023				Cheng, L.T.W.*, Lee, S.K., Li, S.K., Tsang, C.K.	Understanding Resource Deployment Efficiency for ESG and Financial Performance: a DEA Approach. Research in International Business and Finance, 65, 101941.	Yes Appendix 2	Yes	Yes	Yes
2024a				Li, S.K.*, Tsang, C.K., Lee, S.K.	Partially Convex Production Technology and Efficiency Measurement, Journal of Productivity Analysis, doi.org/10.1007/s11123-023-00716-w	Yes Appendix 3	Yes	Yes	Yes

2024b				Li, S.K.*, Tsang, C.K.*, Lee, S.K.*, He, X.*	Regular Variable Returns to Scale Production Frontier and Efficiency Measurement. Operations Research, https://doi.org/10.1287/opre.2021.0470	Yes Appendix 4	Yes	Yes	Yes
	2024a			Tsang, C.K.*, Li, S.K., Lee, S.K.	Assessing the Efficiency of Hong Kong Public Hospital Sector During COVID-19 Pandemic: An Input-oriented Structural Efficiency Approach. Advances in Decision Sciences	Yes Appendix 5a &5b	Yes	Yes	No
			2024c	Li, S.K., Tsang, C.K., Lee, S.K.	Structural Efficiency with Environmental Factors: A Case Study on the Cities of China	Yes Appendix 6	Yes	Yes	No
			2024b	Tsang, C.K., Li, S.K., Lee, S.K.	Revenue Structural Efficiency Measurement with Heterogeneous Subgroup Technology and Prices	Yes Appendix 7	Yes	Yes	No
			2024c	Tsang, C.K., Li, S.K., Lee, S.K.	Estimating the Potential Gain of the Economic Integration of the Guangdong-Hong Kong-Macao Greater Bay Area	Yes Appendix 8	Yes	Yes	No

9. Recognized International Conference(s) In Which Paper(s) Related To This Research Project Was / Were Delivered
(Please attach a copy of each conference abstract)

Month / Year / Place	**Title**	**Conference Name**	**Submitted to RGC** *(indicate the year ending of the relevant progress report)*	**Attached to this Report** *(Yes or No)*	**Acknowledged the Support of RGC** *(Yes or No)*	**Accessible from the Institutional Repository** *(Yes or No)*
04/2023/ Virtual	Partially Convex Production Technology and Efficiency Measurement	The 17th International Conference, Western Economic Association International	Yes Appendix 3	Yes	Yes	Yes
06/2023/ Hong Kong	Estimating the Potential Gain of the Economic Integration of the Guangdong-Hong Kong-Macao Greater Bay Area	International Conference on Hong Kong Studies from Cross-disciplinary Perspective	Yes Appendix 8	Yes	Yes	No
09/2023/ Toronto	Selecting Proxies for Inputs with Limited Data in Data Envelopment Analysis	International Academic Conference on Science, Social Science and Economics	Yes Appendix 1	Yes	Yes	Yes
12/2023/ Hong Kong	Partially Convex Production Technology and Efficiency Measurement	The 11th Hong Kong Economic Association Biennial Conference	Yes Appendix 3	Yes	Yes	Yes

10. Whether Research Experience And New Knowledge Has Been Transferred / Has Contributed To Teaching And Learning
(Please elaborate)

N/A

11. Student(s) Trained
(Please attach a copy of the title page of the thesis)

Name	**Degree Registered for**	**Date of Registration**	**Date of Thesis Submission / Graduation**
N/A			

12. Other Impact

(e.g. award of patents or prizes, collaboration with other research institutions, technology transfer, teaching enhancement, etc.)

N/A

13. Statistics on Research Outputs

	Peer-reviewed Journal Publications	Conference Papers	Scholarly Books, Monographs and Chapters	Patents Awarded	Other Research Outputs (please specify)	
No. of outputs arising directly from this research project	5	4	0	0	Type	No.
					Working papers	3

14. Public Access Of Completion Report

(Please specify the information, if any, that cannot be provided for public access and give the reasons.)

Information that Cannot Be Provided for Public Access	Reasons
N/A	