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Call for Papers

Scope

International Journal of Innovation in Management (IJIiM) is an international, refereed, and semiannual journal published by the Society for Innovation in Management (SIiM). IJIiM aims to describe, assess and foster understanding of the role of innovative technologies, managerial practices and theories. Original and Unpublished manuscripts that investigate theoretical issues or report empirical findings in all aspects of innovation in various management areas are welcomed. Topics of interest include, but are not limited to, the following:

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We cordially invite you to consider submitting your research work to IJIiM. Please send your manuscript to IJIiM@siim.org.tw for submission.

Burden of Proof in Transfer Pricing of Equity Derivatives

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Abstract

Equity derivatives and transfer pricing have become a scholarly focus and financial engineering become an emerging field as the 21st century unfolds. Although the derivatives market has grown exponentially, there is a need for substantial research on transfer pricing.

This article focuses on a transfer pricing litigation case involving global trading in which the National Tax Tribunal in Japan reversed the Tokyo Regional Tax Bureau's decision. Regression analysis was used to examine how the tax tribunal applied the residual profit split method to reject a taxpayer's choice of the hedge fund method.

The hypothesis in this article is: There is a correlation between the number of hours a stock trader works or provides a service and the profit the stock trader earns, which could serve as two variables to test an arm's length price for relative contribution using the residual profit split method. A test of difference in the means would prove that the difference between two variables would affect the significance of the mean price. Regression analysis has been widely used in transfer pricing disputes since it has predictive power to test the assumptions of a model or a transfer pricing method.

The ordinary least square verifies if work on a particular activity is for one related company, then the whole cost of the work with a markup would have to be allocated to the related company. When work involves more than one company, the costs should be allocated in proportion to an objective factor. An objective variable can be allocated using an analysis of working hours derived from a timesheet. Other elements related to turnover, headcount, and telephone calls were used as a way of apportioning the costs.

Keywords: Burden of proof, equity derivatives, transfer pricing, integrated trading, centralized product management

1. Introduction

The article analyzes how an intangible like hedge-funds-related litigation case can provide profits based on a transfer pricing method rather than a hedge fund model. This article particularly focuses on a court case involving global trading, which has become landmark litigation in Japan for three reasons.

(1) It was the first transfer pricing ruling in Japan involving equity derivatives that rejected the hedge fund model.
(2) The burden of proof presented at the court used regression analysis to prove the validity of the residual profit split method.
(3) The profit split indicator and the calculation of risk including income based on the number of services.

The issue in the global trading case relates to the transfer pricing method. The taxpayer claimed that the hedge fund model is appropriate due to the complexity of the derivative and because there were no comparables. The comparability of hedge fund data to the related party transactions was based on the specific facts and circumstances of the hedge fund business.

In the global trading case, the taxpayer had two offices, one in Country X (Japan) and one in Country Y, each issuing stocks at 100%. Company A in Japan (XA) marketed derivatives to Japanese customers and created derivative products. Company A in Japan provided information on derivative products through interbank transactions and engaged in risk management of all financial products.

Financial business was conducted through sales marketing of equity derivatives by XA, Tokyo-based traders. Each trader in Country X and in Country Y engaged in managing clients' tailored stock investments. Traders' remuneration was based on the transaction. Risk management was based on NASDAQ and was in accordance with loss-inducing equity derivatives related to high volatility. The market fluctuation was managed based on dynamic hedging that focused on comprehensive management that targets maximum profit.

When the taxpayer's report on corporate income tax was submitted, the Tokyo Regional Tax Bureau made an initial assessment in 2005 for the tax year from 2000 to 2003. The assessment was based on equity derivatives and a Japanese subsidiary was affiliated as a foreign booking financial entity.

The National Tax Tribunal rejected the Tokyo Regional Tax Bureau's (TRTB) decision on July 2, 2008 because the TRTB excluded the additional measurements for "relative contribution" based on market risk and management functions. A point of significance for this case is the decision by the Tokyo Regional Tax Bureau. It was one of the few cases where the National Tax Tribunal reversed previous decision subsequent to the Adobe Japan case. The sequence of reversals signified emerging views on transfer pricing litigation in Japan.

The tribunal argued that transfer pricing requires the interest rate of an intercompany loan to be backed by third-party evidence. The tribunal also argued that the inclusion of the internal credit rating could be implemented because an internal credit rating can define the applicable intercompany credit spread that is documented in an intercompany loan document. As for relative contribution, the tribunal added interest expenses calculated from the capital used for business but excluded the market risk, which relates to interest expense.

2. Literature Review- Critical Legal Theory and Burden of Proof in Transfer Pricing

From the optimal and equilibrium based transfer pricing theory, the theoretical departure for burden of proof in transfer pricing litigation is approached from the critical legal theory's point of view. Transfer pricing theories and methods from critical legal theory are an essential theoretical departure since transfer pricing involves hidden hierarchical power structures in international taxation, tax treaties, foreign tax credits, and business practice within a country or between countries.

Business culture is considered inseparable from the managerial decision-making process, especially in the pricing of intercompany transactions that take place between affiliated businesses. In critical legal theory, culture is essential in forming the pattern of business or legal practice in which the attribution of power relationships is embedded. The critical theory focuses on the issue of who inherently has the bargaining power or initiative.

In critical legal theory, the traditional demarcation between the mainstream and the periphery is deemed to be the product of the power structure within the society. For instance, data from government white paper would take priority over "insignificant" data. In critical legal theory, there is no "significant data" or "insignificant data". All data are treated with equal importance. From such perspective, the "false positive" has become a concept in international taxation issues. When "big data" is used to detect suspicious transactions, analysis of

data can detect whether a six-year-old girl is being suspected of transferring funds.

From critical legal theory, the Japanese tax litigation is analyzed from the power structure. Tax authorities such as the National Tax Agency or the National Tax Tribunal are treated as a "powerful" entity whose decision deemed to be final and cannot be easily challenged by "powerless" taxpayers who have to be in agreement with the principle of presumption.

For instance, the Fukuoka High Court decision in 1985 held that the burden of proof was on the tax authority. Another landmark tax litigation is "The Bank of Tokyo" case on October 8, 2003 which depicts the particularity of Japanese tax litigation. The case has been a landmark case in a sense that the tax authority was allowed to enter into reconciliation, not as court litigation. At the high court, the reconciliation was achieved at the first trial between Tokyo Ward as a defendant and the Bank of Tokyo as the plaintiff. The decision resulted in Tokyo Ward paying the adjusted tax return in the agreed amount between the two parties.

From these tax litigations, it is assumed that the tax authority has the burden of proof and cases related to the shift of burden of proof to the taxpayer are limited. Typical issues related to burden of proof include the level of evidence, accumulated taxation, dividing necessary expenses and loss, tax avoidance or tax evasion, denial of avoidance, and international taxation.

2.1 Critical Legal Theory and the Logic of Burden of Proof in Transfer Pricing

The notion of allocation in Japanese civil law is different from the common law notion of allocation of the burden of proof. In common law, the legal burden of proving all facts essential to claims normally rests on the plaintiff in a civil suit. The difficulty lies in the need to prove a negative fact or situation within one party's knowledge. In civil law jurisdictions, the burden of persuasion may be dominant in the absence of a jury system compared to the reliance on the burden of proof. In civil law, the burden of proof refers to the duty of each party to prove their claims to convince the judge.

The cause of the inherent limitations imposed on the taxpayer is due to the built-in logic of burden of proof. The logic of burden of proof requires a taxpayer to fulfill the burden of persuasion and does not have a chance to present burden of production. The taxpayer might have the burden of persuasion when and if the court's burden of production is not sufficient. The burden of proof does not automatically shift from the judge to the taxpayer. The inherent nature of burden of proof in transfer pricing assumes that the taxpayer has less bargaining power, to begin with.

2.2 Transfer Pricing Issues and Burden of Proof - Against Hedge Fund Model

Against the hedge fund model, the tax tribunal stated that a transfer pricing method according to the Special Taxation Measures Law (STML) Article 66-4 (2) on comparability was required. The tribunal stated that "no instances could be found in the derivatives field of a set of functions, such as front-end operations marketing, and trading, being dispersed among unrelated parties through service provision transactions with unrelated parties."

The taxpayer involved in the case argued that due to the comparability issue, the hedge fund model can elicit an arm's length transaction. However, the tax tribunal rejected the hedge fund model and adopted the residual profit split method for an arm's length transaction.

The tax tribunal stated that the rationale of the residual profit method must be based on the split among three categories: (1) to the taxpayer, A financial firm, (2) to parent financial firm A in Japan, and (3) the subsidiary of firm B in Country Y as a related party

The taxpayer argued that the foreign related party's contribution would account for the cost of profit such, as "opportunity cost," in addition to the traders' personal cost.

The tax tribunal argued that the global trading firm XA was categorized as an integrated trading firm. The tax tribunal stated that the categorization was based on the Organization for Economic Co-Operation and Development (OECD) classification. The OECD classifies global trading into three types of activities: (1) integrated trading, (2) centralized management, and (3) separate enterprise trading which involves multiple jurisdictions in carrying out transactions. Based on the classification, the tax tribunal stated that timing of distribution of inter-group dividends, functions, and risk was not the issue related to the arm's length transaction for this particular global trading case. The tax tribunal emphasized that integrative trading involves each jurisdiction and thus, "objectivity and certainty" should be the core concept.

The tax tribunal stated the rationale for applying the residual profit split method and the reasons why the Three Basic Methods cannot be "the best method." In reference to the OECD Guidelines, paragraph 115, the tribunal evaluated functions performed, including assets used and risk assumed by personnel. The tribunal explained that commissions from sales activities would be used as data for the comparable uncontrolled price method.

The paragraph 115 of the OECD Guidelines states that the Comparable Uncontrolled Price Method is not suitable for sales and marketing functions in hedge funds due to the complexity of the business. Causes of complexity are "the only data available between independents." The paragraph 115 further states that the data will "relate to the basic sales functions which raise the issue as to whether reasonably accurate adjustments can be made to account for the extra functions performed and risks assumed."

Prior to implementing the residual profit split method in the Global Trading case, the primary task was to distinguish booking functions and profit incurring entrepreneurial functions. Remuneration for booking functions is based on routine business, whereas profit incurring functions are classified as non-routine remuneration due to substantial risks. When arm's length returns are vested to the routine functions, residual profits are divided according to split factors.

2.3 Against Hedge Fund Model Pursuant to Transfer Pricing Guidelines in Special Taxation Measurement Law Enforcement Order and Split of Profit under a Hedge Fund Model

The taxpayer's argument was based on the profit split in a hedge fund model. The profit split in a hedge fund is based on a hedge fund investors' entitlement to profit in return for high risk. Therefore, the hedge fund method is not based on the taxpayer's equity derivatives. In the derivative financial services, hedge funds model charges within the range of 1%-2% of assets, these accounts for operating costs and the management fee. For an incentive fee, 20% of the profit would be rewarded.

The taxpayer claimed that contracts formed with hedge fund managers and investors are separate because managers and investors have a different return on capital's contribution. The hedge fund managers choose to centralize risk bearing functions for risk management and separate trading and risk management.

The tax tribunal rejected the hedge fund model since hedge funds engage in trading in arbitrage opportunities that were not consistent with global trading transactions. Moreover, the taxpayer's business activities consisted of sales and marketing of derivatives.

The tax tribunal commented on the reasons for rejecting the hedge fund model based on the STML Enforcement Article 39-12 (8) clause on income generation. The tribunal stated that the taxpayer did not engage in income-generating business. One of the reasons was that a hedge fund model assumes high risk difference from the taxpayer's equity derivatives business based on the relative contribution in transfer pricing.

The hedge fund model was not admitted because the scope of risk was not the taxpayer's primary business purpose. Measuring the level of contribution in relation to the income generating estimate element was deficient in the global trading case according to STML Enforcement Article 39-12 (8), which is about income generation.

3. Analysis

3.1 Rejection of Hedge Fund Model Due to Company's Proprietary Trading

The tribunal argued that the data presented by the taxpayer was drawn from proprietary trading which inherently was not objective because of a potential conflict of interest involved. The tax tribunal stated that proprietary trading as a business strategy lacked a reliable degree of comparability between hedge funds and global transactions with investment banks.

Hedge fund investors charge fund managers with the same objective. Depending on the facts and circumstances, the remuneration arrangements commonly observed in hedge funds may provide a reasonably reliable comparison for allocating profits involving participants in a firm's "proprietary or quasi-proprietary trading arrangements."

The tax tribunal reiterated that the hedge fund model is appropriate in a "proprietary trading business." The tax tribunal further referred to Paragraph 162 of the OECD Guidelines which states the following about the hedge fund model.

The hedge fund model may be a useful analogy for a proprietary trading business or a trading book in which the strategy is to earn a significant proportion of the income by taking unhedged, proprietary positions to generate significant trading gains…the remuneration arrangements commonly observed in hedge funds may provide a reasonably reliable comparison for allocating profit between participants in a firm's proprietary or quasi-proprietary trading arrangements.

The tax tribunal countered that the taxpayer's claim that it was not "proprietary" because the business was mostly engaged in "booking" functions.

The taxpayer argued the hedge fund model is valid since the remuneration distribution functions were according to the nature of the hedge fund. It claimed that one reason for this is that global trading case is characterized as an integrated function involving the hedge fund managers' business. However, the tribunal stated that traders were rewarded based on the capital raising functions directly linked with a portion of the management fee and the performance fee which have been inconsistent. Another crucial reason was that the taxpayer's business did not identify distribution as a routine business function and did not separate rewarding the traders with a markup on costs.

The taxpayer raised the comparability issue in relation to the benchmarking distribution. The benchmarking distribution in the hedge fund context has traditionally been difficult because of the unavailability of third party benchmarks and lack of internal comparable. While the market practice should reward distribution with 20 or 25% of the management and performance fee, the taxpayer asserted that benchmarking has tended to draw the distribution rate from the long-term fund that makes comparability unrealistic.

From the transfer pricing objectives, the hedge fund method does not depict the facts and circumstances. One of the reasons is that the hedge fund method would likely to result in higher profits from the proprietary booking being allocated to the different trading locations.

The tax tribunal disputed that the hedge fund model can be used in applying the model to the trading location. The tribunal stated that the booking location may follow the OECD guidelines and adopt a reasonably comparable price for benchmarking. However, the tax tribunal focused on the residual profit split method

rather than the benchmarking comparability in hedge fund distribution. In the global trading business case, the financial firm XA Co. was located in Japan and YB Co. was in a foreign country, and the investment management as an integrated team was divided in different places. Businesses were located in different places. Thus, the tax tribunal used the residual profit method for allocating individual performance and contribution.

4. Rejection of Taxpayer's Use of Weighted Average Cost of Capital (WACC)

The tax authority rejected the use of WACC in producing an arm's length price for two reasons. The tax authority claimed that WACC cannot be a way to determine the funding cost. WACC is based on the cost of equity assuming the speculative return to investors and not an actual expense, which lacks objectivity. WACC assumes the cost of equity based on speculative return.

The decision of the tax tribunal to reject WACC was based on the analysis that the cost in WACC is different from the actual cost. The tribunal stated that WACC reflects the theoretical estimate from the return yield which lacks objectivity and certainty. The tax tribunal also reiterated that WACC cannot satisfy the requirements in the Special Taxation Measures Law Enforcement Order 39-12 (8), which focuses on the income-generating contribution and not the cost.

The relationship between proprietary transaction and procurement costs were the two main issues for WACC. The tax tribunal recognized that the taxpayer's business is primarily related to profits from proprietary transactions. Since the taxpayer's procurement costs were from proprietary transactions, the tribunal rejected the argument that procurement cost is a part of the split element.

The taxpayer countered that the issue of the contribution must be related to the notion of "opportunity cost" and credibility of the company in the WACC. The taxpayer argued that the OECD guidelines are for benchmarking purposes. For equity derivative firms that decide on tax advantages, they must utilize tax opportunities that can create shareholder value. Potential tax advantages were claimed by selecting a tax efficient location for treasury and finance activities, they have optimized the capital structure and developing structured finance instruments for transfer prices. For the taxpayer, WACC is a criterion to use when seeking transfer pricing as a tax advantage.

4.1 Rejection Due to the Inapplicability of the Mark-to-Market Rule

The tax authority's decision to reject the WACC was also related to the absence of the mark-to-market rule. The tax tribunal addressed the mark-to-market taxation at realization in reference to Article 61-6 of the Corporate Taxation Law. The tax tribunal argued against the relevance of transfer pricing to the hedge fund manager: how the distribution fee is calculated, different components of the fee, the range of functions that agents perform for hedge fund managers, factors influencing the agents' fee, and duration of the payments made to agents according to Corporate Taxation Law Article 61-6.

The point of Article 61-6 of the Corporate Taxation Law is the notion of the mark-to-market rule. The portion of a derivative as a hedge against possible loss cannot be deemed as income under the mark-to-market rules pursuant to Corporate Taxation Law Article 61-6.

The Article 61-6 of the Japanese Corporate Taxation Law particularly addresses the realization issue. It is equivalent to Section 1256 (a) of the U.S. Internal Revenue Service's Internal Revenue Service Code (which addresses a mark-to-market rule. Mark-to-market rules are for the taxpayer who ascertains the income or loss of asset value by calculating at the beginning and end of a given period.

The tribunal rejected WACC because it does not have the mark-to-market rule that can be used for calculating income. Investment managers calculated profits by deducting the expenses related to routine business functions with a markup on the costs. If portfolio management functions are split between Company A in Japan and Company B in country Y, the residual profits and revenues computation are based on the performance of the individual investment managers in each location because the location is most closely related to the profit generated by each office.

Another reason why the tax tribunal rejected WACC was because of the absence of the role of capital and split elements in WACC. WACC does not address the role of capital but focuses on risk. The tribunal stated that in order to measure the contribution, the profit has to be based on capital. The residual profit split method would recognize the measure of contribution based on capital and not on WACC.

The tribunal assumed that the measurement of traders' contribution based on capital reflects the general trend in global trading firms. Global trading firms would usually try to optimize the capital structure to develop structured finance instruments. When the lender is located in one place, traders' income would be computed either as a capital receipt, which is not taxable, or it can be offset by capital losses.

5. Analysis on Burden of proof in Residual Profit Split Method over Hedge Fund Model

5.1 Reference to OECD Guidelines for Residual Profit Split Method

When the hedge fund model and WACC were rejected, the tribunal stated that the residual profit split method can be implemented. The Residual Profit Split Method is based on the Article 39-12 (8) of the Special Taxation Measures Law, which states that when there are levels of contribution and risk management business in relation to traders' activities, the traders' remuneration and interest payment to maintain the regulatory capital requirement were used in the profit split element. In addition, Part III of the 2010 OECD Transfer Pricing Guidelines was in reference to support of the tribunal's choice of the profit split method. Residual profit split methods are used "when transactions are highly interrelated and may not be evaluated on a separate basis and when both parties contribute significantly to the development of intangibles."

The tax authority presented the computation of profits. The tax authority stated that the taxpayer's business was not related to client-centered activities but to commission-based hedge fund business as a single set of functions. The tax tribunal's computation was based on the taxpayer's basis for profits plus commission-based profits that are categorized as positioning.

Profits = Taxpayer's company group as a whole + transactions, including positioning

Profit split elements were in reference to the profit indicator stated in the Article 39-12 (8) of the Special Taxation Measures Law Enforcement Act The first split element was from a hedge fund trading business and the second split was from contributions. The quantification of market risk was not specified but the overall risk factors were included in split elements.

5.2 Relative Contribution

In the absence of existing comparable, the arm's length computation of the relative contribution of the profit split method had to be justified. The issue that the tax tribunal raised was the relative contribution of traders and hedge fund managers based on the gain or loss in transactions.

The tax tribunal referred to Cabinet Order Article 121-2, which states that derivative transactions are deemed effective for reducing an amount of loss on assets to be hedged when the effectiveness ratio is between 80/100 and 125/100 in any of effectiveness judgments between the time of carrying out the derivative transactions and the end of said accounting period.

The tribunal addressed the structure of the derivative transactions that are carried out to reduce the amount of loss or gain on assets to be hedged and the ratio would be set according to two classifications.

(i) When the market value of the assets to be hedged in the transaction is at the price at the time of derivative transactions exceeds the market value at the end of an accounting period or the value at the time of settlement of the derivative transactions, the ratio is computed by dividing the gain on the said derivative transactions by the exceeding amount.

(ii) When the market value of assets to be hedged at the end of an accounting period or the value at the time of settlement exceeds the value at transaction, the ratio is computed by dividing the loss on the derivative transactions by the exceeding amount.

The tribunal's computation of the relative contribution was in reference to Paragraph 185 of the OECD Guidelines. But the taxpayer argued against the passage "where compensation is used to measure both trading and marketing functions, the compensation of the traders could be multiplied by 1.5 where it could be demonstrated that trader compensation results increase earnings by 1.5 times the profit earned from marketers' compensation."

The taxpayer claimed that, based on the structure of the taxpayer's business, the computation cannot be adopted in a form of "1.5 times the profit earned from marketers' compensation." The taxpayer argued that their business structure was based on three different categories.

XA – in marketing the hedge funds
YB – client-need based derivative trading
Interbank – received information from XA and engaged in risk management

From the structure of the business, the balance sheet and the arm's length "relative contribution" to the profit is computed:

Arm's Length Profits = Profit from A + Profit from XA + Profit from YB

Profits are calculated from the parent A and subsidiary of A Co. in the country X and the subsidiary of B Co. in the country Y was subject for the profit split and for computation of contribution

The taxpayer stated that the profits are to be split so that they have to separate the salary of a marketer, trades, back observer, and the transaction costs. However, the tribunal claimed that the taxpayer business entity is not a separate entity but was part of "an integrated group." Thus, the computation should be:

Taxpayer's business as one entity + profits from clients + profits from proprietary trading

The tribunal did not recognize the source of the taxpayer's business from separate entities since each entity did not bear market risk because each business conducts a client-based transaction. The tribunal concluded that both A Co. in Japan and B Co. in Country Y did not bear market risk since the fees from clients was deemed to be a source of profit

5.3 Interest Expense Added to the Relative Contribution

Between the taxpayer and the tax tribunal, perspectives on the relative contribution with regard to interest expense were different. The tribunal stated that the interest rate should be calculated from the ratio of interest expense to liability on an overall group level.

Interest = ratio of interest expense to liability on overall group level

Expenses incurred from the interest rate are calculated based on the risk in managers' performance. In addition to the interest rate, the tribunal argued that dividends cannot be interpreted as profit pursuant to the STML Enforcement Order 39-12 (8), which states that dividends from the interest cannot be deemed as a contribution to the profit.

5.4 Procedural Profit Split Based on Relative Contribution in the Function

In addition to the increase in the interest rate according to the internal credit rating, the Tokyo District Court determined the relative contribution of each location for the measurement of factors. The tribunal categorized the taxpayer's financial activities into (1) trading, (2) market risk management, (3) sales, (4) settlement, legal, credit research, and accounting, and referred to Paragraph 186 of the OECD Guidelines.

Where the function(s) are performed in more than one location, it will be necessary to determine the relative contribution of each location in the performance of the function. Under a multi-factor formula, it will be necessary to determine the relative contribution of the various locations under each factor. For people, functions and compensation of personnel performing those functions in each location could be used as a factor that reflects the relative contribution of that location to the earnings in the global trading profit.

This is on the basis that there is a correlation between earning profit for the firm and earning compensation for the individuals. The correlation arises because of the performance of key global trading personnel, especially traders, risk managers and specialized marketers, which is crucial to the profitability of global trading.

The residual profit split method separated trading with booking activities having the allocation in the range of 10-25% from profits derived from trading activities. The reminder to the booking location is identified based on sales and marketing allocated between the trading and booking locations.

The tribunal did not include traders' compensation as the relative contribution to the business. The relative contribution made by functions performed by risk managers who were engaged in trading activities. The relative contribution was rejected because traders were not engaged in activities related to market risk since they were engaged in proprietary activities.

6. Regression Analysis in Burden of Proof

6.1 Burden of Proof and the Validity of the Residual Profit Split Method and a Relative Contribution

The tax tribunal excluded the credit risk functions but included the taxpayer's business as an aggregated single entity, adding profit from clients, profits from proprietary trading, and interest to measure the traders' compensation as a relative contribution.

The burden of proof was based on the profit indicator and regression analysis used to find the reliability between the domestic and foreign-related parties, the relationship between traders' working hours or service and the profit or income.

The tribunal had the burden of proof that the labor cost was one of the factors that the trader and business contribution based on rational adjustment. Reasonableness of contribution based on the "relative contribution" was computed. The taxpayer argued that traders' stipend or salary cannot be included in the division element where all risk management business was comprehensively based because the trading business was primarily based on selling and purchasing client equity derivatives. The tribunal rejected the argument and stated that when the option is based on the original assets, which are stocks, the internal risk would be transferred to the foreign-related party who is the party in the contract. The tax tribunal stated that a foreign related party would receive an option fee in lieu of compensation for risk transfer. If the received option fee from clients were higher than the fair market value, then the fee would be deemed to be a profit. The tax tribunal concluded that a fee-based business cannot be directly linked to capital risk and excluded a risk factor in the residual profit split method.

6.2. Validity of Residual Profit Split Method

Regression analysis attempted to seek a correlation between the total work hours and service on research and development. Based on the factors such as the number of work hours in the service sector and computation of profit in relation to the number of hours of work, the estimate of income can be calculated using regression analysis since the service sector is an intangible property.

In order to seek the correlation between the two variables, the total hours of work and income from the trading service, regression analysis was applied. The table shows the contribution in U.S. dollars all in zero. The original data, as it was disclosed, has no actual Yen amounts. The amounts are all zero and the actual dollar amounts are not shown.

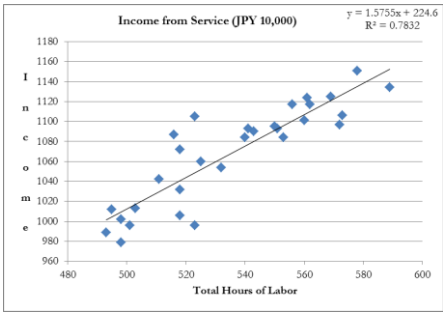
Table 1: The Year and the Amount of Remuneration (income)

Date	Amount	Date	Amount	Date	Amount
April 2000	0000	April 2001	0000	April 2002	0000
May 2000	0000	May 2001	0000	May 2002	0000
June 2000	0000	June 2001	0000	June 2002	0000
July 2000	0000	July 2001	0000	July 2002	0000
Aug. 2000	0000	Aug. 2001	0000	Aug. 2002	0000
Sept. 2000	0000	Sept. 2001	0000	Sept. 2002	0000
Oct. 2000	0000	Oct. 2001	0000	Oct. 2002	0000
Nov. 2000	0000	Nov. 2001	0000	Nov. 2002	0000
Dec. 2000	0000	Dec. 2001	0000	Dec. 2002	0000
Jan. 2001	0000	Jan. 2002	0000	Jan. 2003	0000
Feb. 2001	0000	Feb. 2002	0000	Feb. 2003	0000
Mar. 2001	0000	Mar. 2001	0000	Mar. 2003	0000

From the limited information, profit in relation to the number of hours of work has been computed based on factors such as the number of work hours in the service sector. Since the service sector is an intangible property, the estimate of income can be calculated using the regression analysis.

Table 2: Hours of Work and Income

Year	Hours of Work	Income from Services (JPY10, 0000)	1.575485888
1	493	989	
2	498	1,002	
3	498	979	
4	503	1,013	
5	495	1,012	
6	511	1,042	
7	523	996	
8	501	996	
9	518	1,032	
10	518	1,072	
11	518	1,006	
12	516	1,087	
13	525	1,060	
14	523	1,105	
15	532	1,054	
16	541	1,093	
17	540	1,084	
18	551	1,093	
19	560	1,101	
20	553	1,084	
21	556	1,117	
22	550	1,095	
23	543	1,090	
24	569	1,125	
25	572	1,097	
26	562	1,117	
27	573	1,106	
28	589	1,134	
29	561	1,124	
30	578	1,151	



In order to test the correlation between the total hours of work and income from the trading service, regression analysis was applied.

The result of regression analysis

Multiple Correlation Coefficient R	0.381818898
Multiple Coefficient Determination R^2	0.145785671
Adjusted R^2	0.115278016
Standard Effort	19.83406425
Observation	30

ANOVA

	Degrees of Freedom	Variation	Distribution	Observed Distribution	Significance Level F
Regression	1	1879.877085	1879.877	4.778859	0.037336
Residual	28	11014.92293	393.3901	n/a	n/a
Total	29	12394.8	n/a	n/a	n/a

The result of an ANOVA shows that the P-value was below 5%, or 1.296. When a P-value is less than 5%, the reliability can be further used for t-statistics.

The income from the trading service in Y ordinary least square is generated. R^2 indicates that the split proportion percentage of relative contribution and can be divided among the head office in Tokyo, the XA firm in Country X primarily dealing with marketing, and YB firm in Country Y engaged in trading with banks.R^2 calculation is valid since the risk factors related to the XA firm was not included.

The result is Y = 1.2196 x + 417.1 is understood to show that Y as the ordinary least square method estimates the income from the service. Thus, Y = 1.22 x 500 + 417.1 = 1027 would support the hypothesis of estimated income based on the total work hours and service.

The Y ordinary least square did not include the risk functions due to the "absence of the entrepreneurial functions." Paragraph 261 of the OECD Guidelines, defined its purpose as "in order to determine the relative contribution of the key entrepreneurial risk-taking functions performed in the different parts of the enterprise."

The R^2 = 14% from the Y ordinary least square and it particularly verifies the residual split method addressed by the tax tribunal in an objective way and can be used as proof to argue against the hedge fund model. Labor cost or remuneration of traders as an element of division can be more convincing if the trader's remuneration is calculated in proportion to the profit. The outcome of Y in numbers would serve as a criterion for this proportion. At the same time, the result suggests the application of the least square method can be a "simple" instrumental in computing allocated fees between a booking service and a trading service.

In global trading in which comparable cannot be quantified, this case proves that the residual profit split can satisfy the objectiveness of the method. The split elements were based on salary or other human resource-related expenses, but not on risk or risk management. The taxpayer claimed that risk management was deemed to be an opportunity cost and regulatory interest to meet the minimum interest rate according to regulation. The tax tribunal was against the split element based on risk management due to the predominant business activities where fee-based booking

services are not directly related to market losses.

The compensation of the subsidiaries used for booking proprietary trades has historically caused controversy as tax authorities in the region have adopted different positions regarding the applicability of the OECD Guidelines on this topic. However, results from the regression analysis verify the correlation between labor cost and traders' business contribution.

Derivative-related transactions are integrative and functions can be dispersed among foreign-related parties as a "single unit." It would be difficult to determine the revenues of each foreign-related party. However, by identifying the correlation between labor cost and working hours, the profit split method can prove the allocation of the overall profit according to each foreign-related party's "relative contribution." Relative contribution was according to the proportional adjustment and thus, R^2 verifies the reasonableness of contribution. "Reasonableness of contribution" was computed to be within the amount of permissible risk allowed in the fee-based transactions.

The taxpayer argued that the company as a group primarily engaged in selling and purchasing client equity derivatives and inherently involved more risk than the "amount of permissible risk."

The tax tribunal's argument was that when the option is based on an original asset, such as stocks, internal risk would be transferred to the foreign-related party who are parties by contract. For example, in Country Y, the foreign-related party would receive option fees in lieu of compensation for risk transfer. If the received option fee from clients is higher than the fair market value, then, the fee would be deemed to be profit.

The taxpayer's scope of expense management based on stock fluctuation by hedging and the loss was deemed to be management cost. The tax tribunal did not reject the scope of market risk and its relation to increased management cost. The increased hedge cost derived from management was due to not having profits, but trying to seek profits within the scope of market risk.

The taxpayer's extended argument on risk management was based on the profit division index according to the Special Taxation Measures Law Enforcement Order Article 38. The taxpayer argued that procurement cost had to be adopted. However, this was rejected because "risk cannot be based on estimation." Issues related to whether the comprehensive risk management perspective could have included procurement cost in the regulated capital in Japan and Country Y remained unaddressed. The taxpayer claimed that the profit split index in the STML Article 38 did not reflect on the difference in the actual hedge fund's business and the taxpayer had been engaged with "the role of capital" in the general hedge fund industry.

7. Conclusion - Generalizations on Hedge Funds

The ruling by the tax tribunal suggests two further research questions. One is whether the hedge fund model can further be applied to global trading firms. The other is whether similarities between the hedge fund profit split and residual profit split can be proved. Furthermore, profit distribution according to a hedge fund would be under what reference or referential point in the field of global trading remains as additional issues.

Critiques have pointed that the residual profit split applied in the global trading case was in reference to the OECD Guidelines in terms of transfer pricing.

The taxpayer asserted that the financial capital in a hedge fund is at greater risk than the industrial capital. Returns on financial capital may be less volatile and more predictable than returns on industrial capital. Because so much of their capital is liquid, financial institutions would have greater flexibility than their industrial counterparts in locating their capital in

low-tax jurisdictions while operating their business elsewhere.

The taxpayer commented that the residual profit split method did not reflect the element related to attribution of income to foreign-related firms. Nevertheless, the tribunal made a reference to OECD Paragraph 159, which addressed the issue of hedge funds and comparable. The tax tribunal's argument supported by Paragraph 159 was not entirely convincing.

The taxpayer relied on the general principle of a hedge fund, assuming that there are differences in the comparable and that when the fund managers are seeking high net interest from the investors' perspective, they have rights to claim the profits based on share or dividends. After the ruling in this global trading case which denied the existence of comparable that act like its own hedge fund business, the general practice of implementing the hedge fund model in transfer pricing may have to be re-evaluated.

7.1 Remaining Issues on the Role of Capital and Interest Rate in Regulatory Capital

The taxpayer addressed the role of capital and hedge funds trade in financial products by focusing on the primary economic function of derivative products. The taxpayer's main business objective is to reduce its clients' risk and provide means for them to raise capital more efficiently by reducing the cost of capital.

Contribution elements in the residual profit split method have been questioned by the critiques due to the tribunal's attempt to link contribution to the role of the capital. The tax tribunal emphasized that "the role of capital" in the hedge fund industry relates to the notion that the cost of debt as deductible, whereas the cost of equity is not. The tribunal reiterated that the level of "relative contribution" among traders and business risk can be "best" presented in the residual split profit method. The tribunal admitted that for the residual profit split amount division based on the trader, labor cost and interest payments are valid since there is a correlation between the labor cost and the regulatory capital.

However, in the tax tribunal's final decision, the question of "the role of the capital" remained unanswered. Capital in financial institutions assumes risk and plays a different role in the industrial sector. In the industrial sector, capital is "locked up" in production assets or inventory. The principal risk to which the capital is exposed depends on the managerial competence or the industry-wide decline. In contrast, the capital required to operate a financial institution is generally invested in liquid assets and is subject to large and immediate customer claims based on external events.

The global trading case in Japan is a good example for fund managers who are able to make the most of the transfer pricing to manage their tax rate effectively. Moreover, the burden of proof through regression analysis would be necessary.

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Managing Brands in the Digital Age: A Model of Relevant Competences

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Abstract

Brand management competences are associated with building up and successfully managing brands over a longer period of time. They help companies maintain their focus and stay on course in an increasingly complex and interactive digital world. This is especially important when digitalization affects not only a specific branch or certain functions of a company, but the company as a whole. Surprisingly little research has been done on brand management competences in connection with increasing digitalization. The presented paper aims to fill this research gap. Based on a qualitative survey and a review of existing literature, it identified four new brand management competences, namely (1) brand effectuation competence, (2) brand causation competence, (3) inter-divisional brand translation competence, and (4) intra-divisional brand organization competence. The competences are brought together in an explanatory model in order to provide a first impetus for a holistic view on relevant competences for building and managing brands in the digital age. One important insight for strong brands today is that they have to adjust quickly to new environmental factors by rapidly developing available internal resources and smartly integrating external resources.

Keywords: Brand management, competences, digital age, effectuation, causation

1. Introduction

Brands are "… an organization's promise to a customer to deliver what the brand stands for not only in terms of functional benefits but also emotional, self-expressive, and social benefits" (Aaker, 2014, p. 1). Against this background, it is the task of brand management to position the brand permanently with the relevant target groups by means of a structured process for planning, implementation, and coordination of suitable measures, to build the brand up and to make it more powerful (Aaker, 2014). However, this task is becoming increasingly demanding due to the ongoing digitalization that has been creating new challenges for the management of brands (Temporal, 2010). Some of these challenges are as follows:

(1) today's customers experience a brand not only through various analog contact points, but also through numerous digital points of contact. The sheer number of brand touchpoints makes it extremely difficult to create a homogeneous brand experience across all touch points and communication channels (Baxendale, Macdonald, & Wilson, 2015);

(2) the digital world enables continuous communication between customers, users, potential consumers, and the brand itself (Young, 2014). From the companies' point of view, brand communication is therefore no longer a one-way road, but rather a means of permanent interaction with customers or users of their brand (Ryan, 2014);
(3) highly interactive media require real-time reactions (Ryan, 2014) especially with regard to internet transactions (e-commerce), where customers expect not only a smooth process and the highest level of convenience, but also extremely short response times (Turban, King, Lee, Liang, & Turban, 2015);
(4) today's customers have an *"anywhere, anytime mentality"*, expecting personal and individual communication at any given time. Moreover, they increasingly share their brand experiences with each other, thus influencing brand perception. This may lead to unforeseeable and unfavorable situations that might be challenging to solve (Dänzler, 2014);
(5) brands can no longer be managed by an individual department. It requires coordination with other departments such as IT, human resources, and/or product management (De Swaan Arons et al., 2014).

Consequently, brand managers are confronted with challenges such as increasing (1) brand management complexity, (2) interaction demands of users/customers, (3) need for promptness, (4) uncertainty, and (5) need for coordination at work. These five new challenges have been observed and noted by several researchers (Jasperse, 2015; Johnson, 2015; Cui et al., 2014; De Swaan Arons et al., 2014; Leeflang et al., 2014; Henning-Thurau et al., 2013; Burmann et al., 2012; Aaker, 2011; M'zungu et al., 2010). However, few have given answers on how to resolve them. It is particularly noticeable that current scientific discussions regarding brand-relevant repercussions due to increasing digitalization hardly touch the area of competences. The study at hand aims to close this research gap by answering the following questions:

(1) What are relevant brand management competences?
(2) How can these be defined and differentiated from each other?
(3) How are they interconnected?

This study is structured as follows: Firstly, an introduction into the topic is given, followed by a short presentation of the theoretical foundations. Then the results of a qualitative study on brand management competences will be presented, structured by definition, and finally organized in an explanatory model for brand management competences. The paper concludes with a discussion of its implications and limitations and an outlook on future research opportunities.

2. Theoretical Foundations

Brands are an organization's promise to deliver what it stands for, which is defined by the brand identity and expressed in the brand's characteristic features (Aaker, 2004; Kapferer, 2002). Customers experience these features every time they come into contact with the brand. Consequently, every contact a customer has with the brand leaves its mark – either positively or negatively – and can influence his or her purchase behavior (Nandan, 2005). With this in mind, it is important for organizations to coordinate all brand-relevant activities to allow the brand to reach its full potential and ensure a compelling brand experience for the customers. This requires personal and organizational competences, both at a strategic and at an operative level. The quality of these competences is crucial to the market success of the entire organization (Burmann et al., 2012) since they secure the brand's long-term performance.

According to Gersch et al. (2005, p. 48), competences are defined as "repeata-

ble action potentials of an organization, which are based on the implementation of knowledge, led by laws, and therefore not random". The management of these supply and market processes has become more challenging due to the reasons mentioned in the introduction of this paper. To remain relevant, brands must maintain or even regain their power to influence the customer.

In the past, this power often resulted from a successful market (outside-in perspective) or resource orientation (inside-out perspective) (Kubo, 2015; Burmann et al., 2009). Today, however, adaptability to changing conditions is becoming an increasingly important factor for success. Adaptability to changing conditions is central to the dynamic capabilities approach which combines the classic outside-in and inside-out approaches (Teece, 2013) and describes the potential of a company to reliably solve problems, and to identify and seize opportunities intelligently by fine-tuning and further developing its resource base. This fine-tuning and further development of the resource base does not only include existing resources, but also new and, where appropriate, external resources which have to be made compatible with the organization so that they can be meaningfully integrated. The dynamic capabilities approach is therefore particularly suited to meeting current demands for a relevant, unique, consistent, and successful brand experience across all channels and touch points.

In spite of this clear link, research on identity-based brand management has been rarely applied to the dynamic capabilities approach. There are currently only two scientific elaborations that have addressed this topic. The first study is from Blinda (2007), who reaches the conclusion that strategic brand planning competence, the organizational brand implementation competence, and operative brand implementation competence have a positive impact on the strength of a brand. The second was developed by Burmann et al. (2012). They assume that meta-competences relating to strategic flexibility (e.g. reconfiguration competence, brand information extrication competence and replication competence) have a positive influence on the strength of the brand.

Both approaches recognize and stress the necessity of combining the outside-in and inside-out perspectives in order to generate and maintain competitive advantages. However, since the studies by Blinda et al. (2007) and Burmann et al. (2012) have been conducted almost ten years ago, the necessary skills that are especially relevant in the digital world have not been included.

3. Qualitative Study

3.1 Procedure

In order to form a solid foundation for the identified research topic, expert interviews with 15 top-level executives in leading brand management and marketing positions at well-known companies in various sectors were conducted over a period of three months. These were semi-structured, face-to-face interviews that lasted between 90 and 150 minutes.

3.2 Results

Seven competences transpired as especially relevant to brand management today: Firstly, almost all experts saw a need for (1) a competence to make brand-relevant content transparent across divisions (inter-divisional brand translation competence). The experts also revealed that (2) the competence to quickly and flexibly agree on the necessary organization or composition of project-based teams for brand-relevant measures has become important to many (brand) departments (intra-divisional brand organization competence). In addition, many executives highlighted the need for (3) a competence to make targeted decisions on brand identity, brand planning, and resource allocation (strategic brand development competence). In situations with predictable outcomes, they believe that this requires (4) decision-making competences based on causal

logic (brand causation competence). In situations with uncertain outcomes, however, they were of the opinion that (5) an open attitude towards unforeseeable events on the one hand, and a focus on the available means on the other hand is crucial (brand effectuation competence). Furthermore, many experts stressed the significance of (6) a competence that focuses on absorbing relevant information (brand information absorption competence). Almost all experts also talked about the growing relevance of (7) the competence to shape the customer journey in a way that addresses and fulfills the actual needs (e.g. real-time interaction, automation, and individualization) of customers (brand implementation competence).

Finally, it should be mentioned that many experts spoke about the relevance of a brand controlling competence. However, as this competence seems to interact with most of the other competences in a very complex way, it will not be further explored here.

Table 1 shows a list of definitions that will further clarify and illustrate the brand management competences identified.

Table 1: Brand Management Competences

(1) Inter-divisional brand translation competence	The ability of the brand management department to translate brand messages and values for other departments within the organization.
(2) Intra-divisional brand organization competence	The ability of the brand management department to organize brand-relevant tasks within the department.
(3) Strategic brand development competence	The ability of the organization to make targeted decisions on brand identity, brand planning, and resource allocation (Conant et al., 1990).
(4) Brand causation competence	The ability of the organization to make the right strategic brand decisions based on causal logic in situations with predictable outcomes.
(5) Brand effectuation competence	The ability of the organization to make the right strategic brand decisions based on experience in situations with unpredictable outcomes (Sarasvathy, 2001).
(6) Brand information absorption competence	The ability of the organization to absorb brand-relevant information from its environment – especially information on latent developments (Blinda, 2007).
(7) Operative brand implementation competence	The ability of the organization to convert the strategic brand management concept into actual measures as part of the marketing mix (Blinda, 2007).

3.3 Propositions

Six propositions on the relationships between these constructs were formulated. They will be discussed in the following.

P1: The greater the strategic brand development competence is, the greater the operative brand implementation competence will be.

In the digital environment, the strategic brand development competence should function as a guide for brand management. A head of brand management of a leading B2B company noted in this context: “I have to ... start thinking from the set objective and then to decide what is beneficial to reach this objective. It is essential to have a strong link between the concept and its systematic implementation with the appropriate measures and activities”. Operative brand management thus depends on strategic brand management. Blinda (2007) found that the same is true for the operative brand implementation competence. According to his empirical results, strategic brand development competence strengthens operative brand implementation competence.

P2: The greater the impact of the strategic brand development competence on operative brand implementation competence is, the greater the inter-divisional brand translation competence will be.

According to the experts interviewed, brand-relevant measures are no longer developed in isolation. Rather, brand-related issues and projects are implemented together and harmonized. Consequently, one of the key tasks of brand management is make both the brand and the underlying structure of the brand identity transparent inter-divisionally. One expert likened this to a Venn diagram: Previously, the departments for IT and marketing had hardly any contact points, but today there is a rather significant overlap, and "that means that one has quite a lot to do with each other, … with the added benefit of being able to constantly communicate to each other why this or that makes the brand a little better".

P3: The greater the impact of the strategic brand development competence on the operative brand implementation competence is, the greater the intra-divisional brand organization competence will be.

Most of the experts interviewed in this study believe that the number of options is increasing in the digital world. The head of market research of a global market leader for cleaning technology explained this: "I have to test many, many options, and I encourage my colleagues to walk new paths, to try something new. But it is also important to constantly ask yourself what can I learn from this, how can I do something better and, above all, which team members should I share these insights with so that others can benefit from my lessons learned". The resulting operative challenges can only be met with a flexible organizational structure that will allow rapid information exchange and an effective organization of brand-relevant tasks (Da Silveira et al., 2013).

P4: The greater the brand effectuation competence is, the greater the strategic brand development competence should be.

The director of a large publishing company explains it as follows: "Being ready for change, being open for transformation, and being ready to learn something new, in order to remain flexible and agile. …We try to strategically explain the various challenges connected to the change process, starting with the big picture, and then to demonstrate what that means specifically. … This being said, the focus is always on what we can achieve with our current resources – otherwise we spread ourselves too thin". Another expert adds: "…defining structures, roles and processes while at the same time remaining flexible is surely one of the greatest challenges for brand management at the moment". Strategic brand management is therefore increasingly driven by an endogenous dynamic which enables the company to react agilely, flexibly, and elastically to exogenous influences (Rosenbaum- Elliott et al., 2015).

P5: The greater the brand causation competence is, the greater the strategic brand development competence will be.

The brand manager of a leading mobility and logistics company stated that "...it will remain the task of the brand management to ensure certain results..." and that these results "...are reached mainly through causal means...". Causal logic appears to have a positive impact on strategic brand development even in an environment with strong digitalization.

P6: The greater the brand information absorption competence is, the greater

the strategic brand development competence will be.

One of the most critical competences in the digital age is finding and understanding brand-relevant information in the company's environment, especially on latent developments, and processing them within the organization. The vice president for marketing and brand management of a leading internet portal for German-speaking countries stated: "We try to quickly boost the competences of our employees through empowerment, i.e. getting involved in the task, and applying all the relevant information in order to complete a project in accordance to the strategic parameters and in the interest of the brand – possibly even independently". Burmann et al. (2012) also viewed the brand information absorption competence as being closely intertwined with the strategic brand development competence; thus, increasing the operational potential of a brand by shaping the motivation and commitment of relevant employees.

Figure 1 summarizes the six propositions in form of an explanatory brand management competence model.

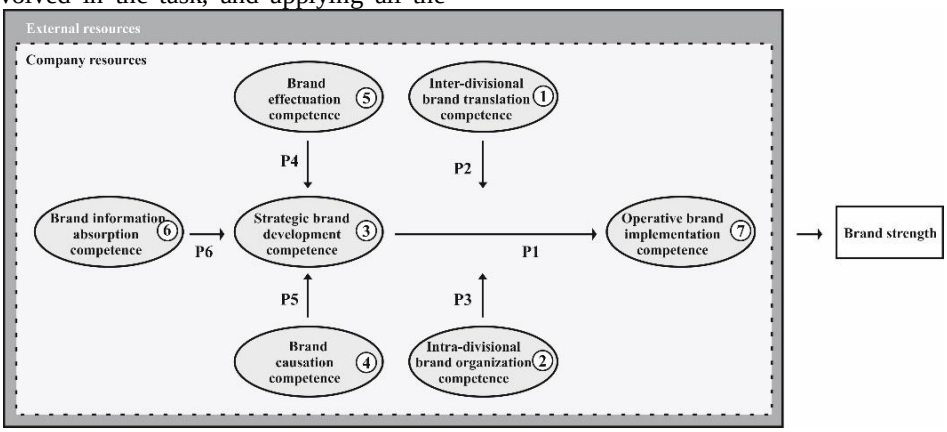

Figure 1: Model of Brand Management Competences
Source: Own Diagram

4. Conclusion and Implications

The study at hand provides important insights into brand management competences in an increasingly digital world. It has several implications, at least three of which are of a theoretical nature.

First, new brand management competences were identified, which have not previously been addressed in literature: (1) inter-divisional brand translation competence, (2) intra-divisional brand organization competence, (3) brand effectuation competence and (4) brand causation competence. Second, it improves our understanding of these competences by defining and discussing them thoroughly. Third, it develops an up-to-date explanatory model that reveals the relationship between these newly identified competences and already known competences, creating a more holistic view of brand management in a digital era.

This study also has a number of implications for management. First, it clarifies that strategic brand development competences are driven by a company's ability to apply newly learned information to reach their targets through a combination of reflection and intuition. Accordingly, employees who understand the needs and wants of the market, who can anticipate new developments at an early stage and can harness these insights for the brand, are becoming increasingly important. The traditional business curriculum, which is primarily based on rational brand decisions, must therefore be expanded to include

innovative approaches that improve employees' intuition. Second, qualitative market research shows that successful brand management today is inherently inter-divisional, i.e. in cooperation with other departments, especially IT and human resources. As a result, it is increasingly important to foster inter-divisional understanding of the brand and to anchor key brand messages in employees' minds. This is easier if brand management employees have an interdisciplinary background and strong communication skills. Third, the study shows that the brand implementation competence is still fundamental to brand management. Aaker's (2010) statement "strong brands do not just happen" is therefore just as relevant in the digital age. However, due to the increasing digital dynamic and uncertainty, brand management must be significantly more agile than in the past.

5. Limitations and Future Research

This study is a first step to better understanding brand competences that are relevant in the digital age. However, like any study, it has several limitations that may be addressed by further research.

The authors of the study understand that the scope of the qualitative market research can still be extended. Additional interviews, especially with companies outside of Germany, might help identify further variables and constructs, as well as improve existing insights. Furthermore, it must be noted that the study at hand is a purely explorative research and so the causal relationships described in Figure 1 require confirmation. Quantitative research in particular is considered useful in this regard. Last but not least, while this study identified numerous variables and constructs, these must still be further operationalized in order to conduct such quantitative research.

Regardless of these limitations, the study at hand shows that research on brand competences in the digital era is still in its infancy stage. As this is a highly dynamic field, it will offer a wide range of research opportunities for years to come.

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Research for HCODEQ Method

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Abstract

This paper presents a comparison of the convergence properties between the HCODEQ, CODEQ, and differential evolution (DE) methods. The concepts of chaotic search, opposition-based learning, and quantum mechanics are used in the CODEQ method to overcome the drawback of selecting the crossover factor and scaling factor used in the DE method. However, a larger population size must be used in the CODEQ method. That is a drawback for all evolutionary algorithms (EAs). To overcome this drawback, acceleration operation and migrating operation are embedded into the CODEQ method, i.e. HCODEQ method. The migrating operation can be used to maintain the population diversity, which guarantees a high probability of obtaining the global optimum. And the aim of the accelerated operation is to speed up the convergence. However, this faster convergence also leads to a higher probability of obtaining a local optimum because the diversity of the population descends faster during the solution process. So, these two operations can act as a trade-off operation for the population diversity and convergence to accelerate the search of the global solution. To prove the convergence property of the HCODEQ method, four benchmark functions from the literature are used to compare the performance of the HCODEQ, CODEQ, and DE methods. Numerical results show that the HCODEQ method outperformed other methods.

Keywords: HCODEQ, CODEQ, DE, migrating operation, accelerated operation

1. Introduction

CODEQ (Omran & Salman, 2009; Omran & Salman, 2009; Omran & Salman, 2010; Omran, 2010) is a population-based, parameter-free meta-heuristic algorithm integrating concepts from chaotic search, opposition-based learning, Differential Evolution (DE) and quantum mechanics. DE as developed by Stron and Price (1996). It has proved to be a promising candidate in solving real-valued optimization problems (Amjad, Salam & Saif, 2015; Zamuda & Brest, 2014; Havangi, Nekoui, Teshnehlab & Taghirad, 2014; Reddy & Sahoo, 2014; Liang, Qu, Mao, Niu & Wang, 2014; Chiou & Chang, 2010; Chiou & Chang, 2009; Price, 1997). DE is a stochastic search and optimization method. The fittest in an offspring competes one-on-one with that of the corresponding parent, which is different from the other EAs. This type of competition will lead to a faster convergence rate. However, this faster convergence also leads to a higher probability of obtaining a local optimum because the diversity of the population descends faster during the solution process. To maintain the diversity of the population, a larger population size must be used like the other evolutionary algorithms (EAs) use. So the selection of parameters is very important for the DE method because some parameters are more sensitive to the problem. For example, a fixed scaling factor is used in DE. Using a smaller scaling factor, DE becomes increasingly robust. However, much computational time should be spent to evaluate the objective function. DE with a larger scaling factor result generally falls

into local solution or non-convergence. Two parameters including the scaling factor and mutation operator are more difficult to set in DE. So, the concept of quantum mechanics is needed in CODEQ to overcome these two parameters selection problem. At the same time, the concepts of opposition-based learning and the chaotic search can be combined as an excluded operation used to speed up the convergence. The basic concept of opposition-based learning is the consideration of an estimate and its corresponding opposite estimate simultaneously to approximate the current candidate solution (Omran & Salman, 2009). And chaotic sequences can be used to test the searching ability of heuristic optimization method (Omran & Salman, 2009). Due to the need to execute the crossover operation, DE is not rotationally invariant (Omran & Salman, 2009). To avoid the problem, the crossover operation of DE was removed in CODEQ. However, a larger population size is still used in CODEQ method. That's a drawback for all evolutionary algorithms (EAs).

To overcome the problem associated with a larger population size used in CODEQ algorithm, two operations including acceleration operation and migrating operation are embedded into original CODEQ method called HCODEQ method. The use of these two operations act as a trade-off operator which can increase the convergence speed without decreasing the diversity among individuals. Migrating operation maintains the diversity of population, which guarantees a high probability of obtaining the global optimum. And the accelerated operation is used to accelerate the convergence. To illustrate the convergence property of the proposed HCODEQ method, four benchmark functions from the literature are used to compare the performance of the proposed method with the HCODEQ, CODEQ, and DE methods in this study. From the computation results, it is observed that the convergence property of the HCODEQ method is better than the other methods.

2. HCODEQ Method

The main idea of the HCODEQ method is to use two operations, migrating operation and acceleration operation, to act as a trade-off operator to overcome the drawback associated with the use of a larger population size in the CODEQ method. The use of the acceleration operation can speed up the convergence of the HCODEQ. And the population diversity can be maintained by the migrating operation. The process of the HCODEQ method is briefly described in the following.

Step 1. Initialization

Input system data and generate the initial population. The initial population is chosen randomly and would attempt to cover the entire parameter space uniformly. The uniform probability distribution for all random variables as following is assumed as:

$$Z_i^0 = Z_{min} + \sigma_i \cdot (Z_{max} - Z_{min}), i = 1, \dots, N_p \quad (1)$$

where $\sigma_i \in (0, 1]$ is a random number. The initial process can produce N_p individuals of Z_i^0randomly.

Step 2. Mutation operation

The essential ingredient in the mutation operation is the difference vector. Different from the DE algorithm, the concept of the quantum mechanics (Omran & Salman, 2009; Omran & Salman, 2009; Omran & Salman, 2010; Omran, 2010) is used to generate the noise replica from the individual parent in HCODEQ algorithm which is expressed as follows:

$$\hat{Z}_i^{G+1} = Z_i^G + (Z_{i1}^G - Z_{i2}^G) \cdot \ln(1/u), i = 1, \dots, N_p, i1 \neq i2 \neq i \quad (2)$$

where $\mathrm{u} \in (0, 1]$ is a random number.

Step 3. Estimation and selection

$$Z_i^{G+1} = argmin\{f(Z_i^G), f(\hat{Z}_i^{G+1})\} \quad (3)$$

$$Z_b^{G+1} = argmin\{f(Z_i^G)\} \quad (4)$$

where $\arg\min$ means the argument of the minimum.

Step 4. Exclude operation if necessary

To increase the convergence of the HCODEQ algorithm, the excluded operation is considered. First, a new individual is created as follows:

$$Z_w^{G+1} = \begin{cases} Z_{min} + Z_{max} - \gamma \cdot Z_{worst}^{G+1}, & if\ \delta \le 0.5 \\ Z_{best}^{G+1} + \left| Z_{i1}^{G+1} - Z_{i2}^{G+1} \right| \cdot (2 \cdot c^{G+1} - 1), & otherwise \end{cases} \quad (5)$$

where γ and δ are randomly generated numbers uniformly distributed in the range of (0,1). Z_{worst}^{G+1} and Z_{best}^{G+1} are the worst and best individuals in the (G+1)th generation. c^{G+1} is the chaotic variable defined as follow:

$$c^{G+1} = \begin{cases} c^G/p, & if\ c^G \in (0,p) \\ (1-c^G)/(1-p), & if\ c^G \in [p,1) \end{cases} \quad (6)$$

where c^0 and p are initialized randomly within the interval (0,1).

The worst individual in the G-th generation is replaced by the generated individual if the fitness of the generated individual is better than that of the worst individual in the G-th generation.

Step 5. Migrating operation if necessary

In order to effectively enhance the investigation of the search space and reduce the choice pressure of a small population, a migrating operation is introduced to regenerate a new diverse population of individuals. The new population is yielded based on the best individual Z_b^{G+1}. The g-th gene of the i-th individual is as follows:

$$Z_{ig}^{G+1} = \begin{cases} Z_{bg}^{G+1} + \mu_i \cdot (Z_{g\,min} - Z_{bg}^{G+1}), if\ \beta < (Z_{bg}^{G+1} - Z_{g\,min})/(Z_{g\,max} - Z_{g\,min}) \\ Z_{bg}^{G+1} + \mu_i \cdot (Z_{g\,max} - Z_{bg}^{G+1}), otherwise \end{cases} \quad (7)$$

where μ_i and β are randomly generated numbers uniformly distributed in the range of $[0,1]$; $i = 1, \ldots N_p$; and $g = 1, \ldots, n$.

The migrating operation is executed only if a measure fails to match the desired tolerance of population diversity. The measure is defined as follows:

$$\varepsilon = \sum_{\substack{i=1 \\ i \neq b}}^{N_p} \sum_{g=1}^{n} \eta_Z / \left(n \cdot (N_p - 1) \right) < \varepsilon_1 \quad (8)$$

where

$$\eta_Z = \begin{cases} 0, if\ \varepsilon_2 < \left| \frac{Z_{gi}^{G+1} - Z_{bi}^{G+1}}{Z_{bi}^{G+1}} \right| \\ 1, otherwise \end{cases} \quad (9)$$

Parameters $\varepsilon_1, \varepsilon_2 \in [0,1]$ express the desired tolerance for the population diversity and the gene diversity with respect to the best individual. η_Z is the scale index. From (8) and (9), it can be seen that the value ε is in the range of $[0,1]$. If ε is smaller than ε_1, then the migrating operation is executed to generate a new population to escape the local point; otherwise, the migrating operation is turned off.

Step 6. Acceleration operation if necessary

When the best individual in the present generation cannot be improved any longer by the mutation operation, a decent method is then employed to push the present best individual towards attaining a better point. The accelerated phase is expressed as follows:

$$Z_b^{G+1} = \begin{cases} Z_b^{G+1}, if\ J(Z_b^{G+1}) < J(Z_b^G) \\ Z_b^{G+1} - \alpha \nabla J, otherwise \end{cases} \quad (10)$$

where Z_b^G denotes the best individual as obtained from equation (4). The gradient of the objective function, ∇J, can be approximately calculated by finite difference. The step size $\alpha \in (0,1]$ in (10) is determined by the descent property. Initially, α is set to one to obtain the new individual.

Step 7. Repeat step 2 to 6 until the terminal conditions are achieved.

The computational process of the HCODEQ is stated using a flowchart as shown in Figure 1.

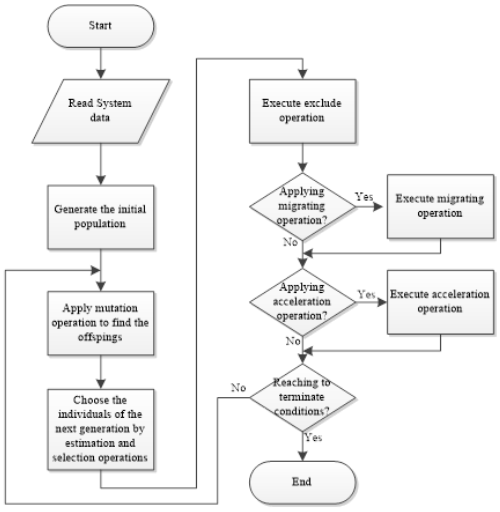

Figure 1: Main Calculation Procedures of the HCODEQ Method

3. Examples

The standard benchmark functions from the literature are frequently used to achieve the testing for reliability, efficiency and validation of optimization algorithms. To validate and compare the performance of optimization algorithms, the benchmark functions should have diverse properties, including modality, separability, and valley landscape so that they can be truly useful to test new algorithms in an unbiased way (Jamil & Yang, 2013; Molga & Smutnicki, 2005). Four benchmark functions are investigated and the computation results are used to compare the performance of the HCODEQ method with that of the CODEQ and DE methods.

Example 1: Let us consider the minimization problem which is described by:

$$\min_{Z_1,Z_2} J(Z_1,Z_2) = 100(Z_1^2 - Z_2)^2 + (1 - Z_1)^2 \quad (11)$$

where $-2.048 \leq Z_1 \leq 2.048$ and $-2.048 \leq Z_2 \leq 2.048$.

The first benchmark function is a Rosenbrock's Valley Function. This is a continuous, differentiable, non-separable, scalable, and unimodal function. Rosenbrock's valley is a classic optimization problem, also known as the banana function or the second function of De Jong. The global optimum lies inside a long, narrow, parabolic shaped flat valley. To find if the valley is trivial, however, convergence to the global optimum is difficult and hence, this problem has been frequently used to test the performance of optimization algorithms. This function has a global minimum value of 0 at $(Z_1,Z_2) = (1,1)$. To verify the performance of the HCODEQ method, the convergence property of the HCODEQ method, CODEQ method and DE method are compared via this example. The setting-factors were used in the HCODEQ method to solve this example. The population size is set to 5. The maximum generation is 300. The tolerances of the gene diversity and population diversity are set to 0.01 and 0.1, respectively. The setting-factors used in the CODEQ method to solve this example as follows. The population size is set to 5. The maximum generation is 300. These initial-setting factors for the DE method are the same as that for the CODEQ except that DE uses the scaling factor fixed to 0.1 and the crossover factor fixed to 0.5. For comparison, the six strategies of mutation operation of DE method are respectively used to solve this example. The solution for this example is repeatedly solved one hundred times. The best and worst values among the best solutions of the one hundred runs are respectively expressed in Table 1. The average for the best solutions of the one hundred runs and the standard deviation with respect to the average are also shown in this table. A smaller standard deviation implies that almost all the best solutions are close to the average best solution. That is, it has low sensitivity with respect to the different initial population. From the Table 1, the standard deviation for the HCODEQ method is smaller than all mutation strategies of DE method and CODEQ method. And the average best value of the HCODEQ method is smaller than DE and CODEQ methods. So, the parameter selection problem is alleviated. That implies that the HCODEQ method is a robust method compared with DE and CODEQ methods. Table 2 lists the computational results when the population size is reassigned to 10 to solve this example one hundred times again. From the computation results, the convergent properties of the HCODEQ method are better than the DE method and CODEQ method. The numbers of the parameter used in the HCODQ, DE, and CODEQ methods are 4, 5, and 2, respectively. Although the number of the parameters used in HCODEQ method is greater than that of the CODEQ method, the parameter selection problem in HCODEQ method is alleviated than in the CODEQ method. The number of times that these best solutions were smaller than 0.00001 are also shown in Tables 1 and 2. From Table 1, the number of the successful runs for the best solutions that were smaller than 0.00001 is 40, 29, 44, 73, 70, and 19

for six different strategies of mutation operations. The number of successful runs for the best solutions that were smaller than 0.00001 is 79 and 98 in the CODEQ and HCODEQ methods, respectively. From Table 2, the number of successful runs for the best solutions that were smaller than 0.00001 is 89, 98, 100, 100, 99, and 96 for six different strategies of mutation operation. The number of the successful runs for the best solutions that were smaller than 0.00001 is 100 for both the CODEQ and HCODEQ methods. Based on the computational results, the convergence property of the HCODEQ method is outperformed than the DE and CODEQ methods.

Table 1: Computation Results for One Hundred Runs of Example 1, population size = 5

Mutation Strategy	**1**	**2**	**3**	**4**	**5**	**6**	**CODEQ**	**HCODEQ**
Best	3.10e-17	4.35e-23	1.52e-24	1.98e-12	2.47e-14	1.60e-19	0	1.77e-10
Worst	9.290304	149.9470	8.871615	1.927184	8.136053	3665.115	6.304407	0.0042637
Average	0.371408	2.21562	0.558783	0.028183	0.093700	37.36613	0.103410	4.31e-05
STD	1.270686	15.00289	1.470137	0.195969	0.815074	366.4436	0.638052	4.26e-04
Count	40	29	44	73	70	19	79	98

Table 2: Computation Results for One Hundred Runs of Example 1, population size = 10

Mutation Strategy	1	2	3	4	5	6	CODEQ	HCODEQ
Best	3.99e-19	1.99e-26	0	2.70e-15	5.04e-16	7.78e-20	0	1.66e-10
Worst	2.873036	0.457369	3.02e-09	2.48e-06	1.32e-05	1.087578	1.61e-27	5.79e-07
Average	0.039089	0.008802	3.02e-11	6.24e-08	1.92e-07	0.010948	1.67e-29	8.94e-08
STD	0.290182	0.061975	3.02e-10	3.29e-07	1.43e-06	0.108753	1.61e-28	1.24e-07
Count	89	98	100	100	99	96	100	100

Example 2. Let us consider the minimization problem is described by

$$\min_{Z_1 - Z_2} J(Z_1, Z_2) = \frac{1}{\frac{1}{K} + \sum_{j=1}^{25} f_j^{-1}(Z_1, Z_2)} \tag{12}$$

where $f_j(Z_1, Z_2) = c_j + \sum_{i=1}^{2} (Z_i - a_{ij})^6$, $-65.536 \le Z_1, Z_2 \le 65.536$, $K = 500, c_j = j$ and

$$[a_{ij}] = \begin{bmatrix} -32 & -16 & 0 & 16 & 32 & -32 & -16 & \dots & 0 & 16 & 32 \\ -32 & -32 & -32 & -32 & -32 & -16 & -16 & \dots & 32 & 32 & 32 \end{bmatrix}$$

The second benchmark function is the Fifth function of De Jong. This is a multimodal test function. This function has a global minimum value of 0.998 at $(Z_1, Z_2) = (-32, -32)$ as also shown by Michalewicz (1999).

In Example 2, the parameters for the HCODEQ, CODEQ, and DE methods are selected as those of Example 1. The solution for this example is repeatedly solved one hundred times. The best and worst values among the best solutions of the one hundred runs are respectively expressed in Table 3. The average for the best solutions of the one hundred runs and the standard deviation with respect to the average are also shown in this table. From Table 3, the standard deviation for the HCODEQ method is smaller than all mutation strategies of DE method and CODEQ method. And the average best value of the HCODEQ method is smaller than DE and CODEQ methods. That implies that the HCODEQ method is a robust method compared with DE and CODEQ methods again. From the computation results, the convergent properties of the HCODEQ method are better than that of the DE method and CODEQ method. Table 4 lists the computational results when the population size is reassigned to 10 to solve this example one hundred times again. From Table 4, the standard deviation for the HCODEQ methods is smaller than that of all mutation strategies of DE and CODEQ methods. And the average best value of the HCODEQ method is less than that of DE and CODEQ methods. A smaller standard deviation also implies that the method has a low sensitivity with respect to the different initial population. So the parameter selec-

tion problem of the HCODEQ method is alleviated.

Example 3: Let us consider the minimization problem as described by

$$\min_{z_1,z_2} J(z_1,z_2) = [1+(z_1+z_2+1)^2(19-14z_1+3z_1^2-14z_2+6z_1z_2+3z_2^2)]\times[30+(2z_1-3z_2)^2(18-32z_1+12z_1^2+48z_2-36z_1z_2+27z_2^2)] \quad (13)$$

where

$$-2 \le z_1, z_2 \le 2$$

The third benchmark function is the Goldstein Price function which is a continuous, differentiable, non-separable, non-scalable, and multimodal function. This function has a global minimum value of 3.00 as also shown by Michalewicz (1999). In Example 3, the parameters for the HCODEQ, CODEQ, and DE methods are selected as those of Examples 1 and 2. The solution for this example is repeatedly solved one hundred times. The best and worst values among the best solutions of one hundred runs are expressed in Table 5. The average for the best solutions of one hundred runs and the standard deviation with respect to the average are also shown in this table. Table 6 lists the computational results when the population size is re-assigned to 10 to solve this example one hundred times again. From the computational results in Tables 5 and 6, the convergence property of the HCODEQ has outperformed other methods.

Example 4: Let us consider the minimization problem as described by:

$$\min_{z_1,z_2} J(z_1,z_2) = \left(4-2.1z_1^2+\frac{z_1^4}{3}\right)z_1^2 + z_1z_2 + (-4+4z_2^2)z_2^2 \quad (14)$$

where $-3 \le z_1 \le 3$ and $-2 \le z_2 \le 2$

The fourth benchmark function is the Six-Hump Camel Back Function. The Six-Hump Camel Back Function is a global optimization test function. Within the bounded region of it owns six local minima, two of them are global ones (Molga & Smutnicki, 2005). Like the Goldstein Price function, the Six-Hump Camel Back Function is also a continuous, differentiable, non-separable, non-scalable, and multimodal function. This function has a global minimum value of -1.0316 as also shown by Michalewicz (1999). In Example 4, the parameters for HCODEQ, CODEQ, and DE methods are selected as those of Examples 1, 2, and 3. The solution for this example is repeatedly solved one hundred times. The best and worst values among the best solutions of the one hundred runs are respectively expressed in Table 7. The average for the best solutions of the one hundred runs and the standard deviation with respect to the average are also shown in this table. Table 8 lists the computational results when the population size is reassigned to 10 to solve this example one hundred times again. From the computational results in Tables 7 and 8, the convergence property of the HCODEQ has outperformed that of other methods.

Table 3: Computation Results for One Hundred Runs of Example 2, population size = 5

Mutation Strategy	1	2	3	4	5	6	CODEQ	HCODEQ
Best	0.998004	0.998004	0.998004	0.998004	0.998004	0.998004	0.998004	0.998004
Worst	23.80943	20.15349	23.80943	21.07269	20.15349	29.46829	12.67051	10.76318
Average	6.638564	7.660642	9.558399	3.534609	3.467216	7.254276	5.137431	1.514822
STD	5.958980	5.351153	6.847977	4.415153	4.328542	5.999762	3.963695	1.490098
Count	23	9	12	50	58	18	22	75

Table 4: Computation Results for One Hundred Runs of Example 2, population size = 10

Mutation Strategy	1	2	3	4	5	6	CODEQ	HCODEQ
Best	0.998004	0.998004	0.998004	0.998004	0.998004	0.998004	0.998004	0.998004
Worst	12.67051	16.44091	21.98841	10.76318	15.50382	10.76318	11.71870	1.992554
Average	3.679119	4.374463	7.520116	1.677553	1.55700	2.51205	1.875342	1.007950
STD	3.401745	4.240636	5.983056	1.831971	1.997564	2.771254	1.936128	0.099455
Count	43	28	10	77	84	60	72	97

Table 5: Computation Results for One Hundred Runs of Example 3, population size = 5

Mutation Strategy	1	2	3	4	5	6	CODEQ	HCODEQ
Best	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Worst	86.43120	84.00614	1226.673	84.00000	84.00000	840.0000	84.00	3.00
Average	8.218919	13.37741	36.23754	10.29000	5.430000	21.39463	5.5444273	3.00
STD	17.15447	22.96446	148.3339	21.31689	12.19311	85.47584	10.257319	2.37e-10
Count	83	70	66	87	95	55	86	100

Table 6: Computation Results for One Hundred Runs of Example 3, population size = 10

Mutation Strategy	1	2	3	4	5	6	CODEQ	HCODEQ
Best	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Worst	3.00	84.00	84.00	30.00	3.00	3.00	3.00	3.00
Average	3.00	5.160005	5.70	3.81	3.00	3.00	3.00	3.00
STD	1.84e-15	9.918590	12.43529	4.629058	2.22e-15	1.59e-15	2.48e-15	2.56e-15
Count	100	94	94	97	100	100	100	100

Table 7: Computation Results for One Hundred Runs of Example 4, population size = 5

Mutation Strategy	1	2	3	4	5	6	CODEQ	HCODEQ
Best	-1.0316	-1.0316	-1.0316	-1.0316	-1.0316	-1.0316	-1.0316	-1.0316
Worst	-0.21546	-0.21546	-0.21546	-0.21546	-0.21546	-0.11326	-1.008884	-1.0316
Average	-1.01513	-1.03163	-0.98741	-1.01531	-1.02347	-1.00195	-1.031298	-1.0316
STD	0.114818	0.081609	0.181142	0.114839	0.081616	0.161086	0.0022964	1.64e-08
Count	93	95	88	98	99	86	86	100

Table 8: Computation Results for One Hundred Runs of Example 4, population size = 10

Mutation Strategy	1	2	3	4	5	6	CODEQ	HCODEQ
Best	-1.0316	-1.0316	-1.0316	-1.0316	-1.0316	-1.0316	-1.0316	-1.0316
Worst	-1.0316	-1.0316	-1.0316	-1.0316	-1.0316	-1.0316	-1.0316	-1.0316
Average	-1.0316	-1.0316	-1.0316	-1.0316	-1.0316	-1.0316	-1.0316	-1.0316
STD	1.12e-15	4.63e-14	1.12e-15	1.12e-15	1.85e-12	1.12e-15	1.12e-15	5.95e-09
Count	100	100	100	100	100	100	100	100

4. Conclusion

The convergence property of HCODEQ, CODEQ, and DE methods are compared via four benchmark functions from the literature. The concepts of chaotic search, opposition-based learning, and quantum mechanics are used in the CODEQ method to overcome the drawback in selecting the crossover factor, scaling factor, and mutation operator used in the original differential evolution (DE) method. The main idea for the HCODEQ method is to use two operations, migrating operation and acceleration operation, to act as a trade-off operator to overcome the drawback associated with the use of a larger population size in CODEQ method. The use of the acceleration operation can speed up the convergence of HCODEQ. And the population diversity can be maintained by the migrating operation. The numbers of the parameter used in the HCODQ, DE, and CODEQ methods are 4, 5, and 2, respectively. Although the number of the parameters used in HCODEQ method is greater than the CODEQ method, the parameter selection problem in HCODEQ method is alleviated than in CODEQ method. From the computational results of the four examples, the convergence property of the HCODEQ method is better than that of CODEQ and DE methods. Finally, the proposed HCODEQ method can be used to solve the optimization problem in the management field, for example, production and inventory control, logistics network, and so on.

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External Knowledge Factors Important for the Growth of Technology-based SMEs in Non-Clustered Regions

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Abstract

Several studies have suggested that knowledge spill-overs have significant consequences for small firm performance especially in clusters; however, past empirical findings have largely ignored the question of whether knowledge spill-overs also matter for small firms in non-clustered regions. Extending previous research, this paper analyzes the impact of different types of knowledge spill-over mechanisms on small firm performance in non-clustered regions. This paper argues that due to the greater disadvantage of non-clustered small firms in research and development (R&D) and local knowledge resources, performance of such firms will be significantly influenced by 'imitation of non-local firms through reverse engineering', which requires less R&D. This study utilized a survey on non-clustered and clustered (as control group) technology-based small firms in the East of England, and considered firm specific factors, international spillover mechanisms and technology acquisition through market mechanisms. The findings suggest that imitation spill-overs have a significant positive impact on the growth performance (and innovativeness) of small firms in non-clustered regions. Key policy implication is that while policies for promoting small firm performance through university research appear to be appropriate for clustered regions, non-clustered regions may need to adopt different policies that will allow small firms to imitate other technologies through appropriate legal means.

Keywords: Knowledge spillovers, technology innovation policy, small firm growth, clusters, non-clusters

1. Introduction

1.1. Article Length

The type of knowledge factors that matter for the growth performance of technology-based small firms in non-clustered regions is a question of great importance. Non-clustered regions refer to regions that lack geographic concentration of firms and employment in technology-based sectors (Suarez-Villa and Walrod, 1997; Falzeinstein et al., 2012; Branco and Lopes, 2013); therefore, they are considered disadvantaged in terms of local knowledge resources (Acs, 2002; Stuart & Sorenson, 2003; Branco & Lopes, 2013; Lapple et al., 2016; Isaksson et al., 2016). Studying the nature of knowledge factors that influence the growth of small firms in non-clustered regions is particularly important because in spite of their dearth of local knowledge resources, a substantial number of high-growth firms are located in these regions (Acs et al., 2008; Spencer et al., 2012). In the United States (US) for example, almost 'one-quarter' of high growth firms are found outside clustered areas (Acs et al., 2008). In Germany, Schroder (2013) found that initiated Information and Communications Technology (ICT) clusters only play a limited role in enhancing knowledge of diffusion since high-growth firms are rarely actively involved in a cluster.

In Canada, only 55% of high-growth firms belong in clusters (Spencer et al., 2012), while the remaining 45% are non-clustered. Moreover, in the United Kingdom (UK), though high growth firms are involved in leading clusters, such firms are found in other regions (Berr, 2008); thus, suggesting the need to understand the factors that drive the growth of firms in non-clustered regions. The lack of understanding of the unique sources of knowledge needed to allow small firm growth in these regions result in many government policies being patterned after cluster-based policies.

In this context, the most commonly held belief about knowledge sources that drive small firm growth is shaped by the well-publicized *Localized Knowledge Spill-over Theory* (Audretsch & Lehman, 2005a, b; Audretsch & Dohse, 2007; Raspe & van Oort, 2008; Chyi et al., 2012). According to this theory, technology-based small firms often have dearth of internal resources that are needed to conduct research development (R&D), and are therefore propelled by localized knowledge spill-overs which are knowledge externalities "bounded in space" that allow companies operating nearby key knowledge sources to introduce innovations and experience growth at a faster rate than rival firms located elsewhere (Audretsch & Lehman, 2005a, b; Audretsch & Dohse, 2007; Raspe & van Oort, 2008; Beaudry & Swann, 2009; Maine et al., 2010; Lapple et al., 2016; Isaksson et al., 2016). Consequently, knowledge resources such as university research serve as an important source of knowledge spill-overs that influence firm growth performance in regional clusters (Audretsch & Lehman, 2005a, b; Audretsch & Dohse, 2007; Raspe & van Oort, 2008; Beaudry & Swann, 2009; Maine et al., 2010; Goetz et al., 2016). The question of whether or not knowledge spill-overs matter for small firm performance in non-clustered regions has remained largely unexplored due to an overwhelming focus on knowledge spillovers and small firm performance in clusters (Saxenian, 1994; Audretsch, 1998; Audretsch & Lehman, 2005a, b; Audretsch & Dohse, 2007; Beaudry & Swann, 2009; van Beers & van der Panne, 2011; Ghio et al., 2016). This is in spite of having a high tendency to imitate cluster-based knowledge spill-over policies in regions that lack clusters. This is a crucial issue because many regions lacking clusters have launched or are currently launching innovation policies based on knowledge spill-over policies from clustered regions. According to Jaffe (1989), a country that improves its university research will increase innovation locally by attracting R&D from industry.

Government policy makers for non-clustered regions, when this type of policy approach is followed, may have difficulties in solving disparities in innovation capacities because firms belonging to the richest regions are able to spend more money on local R&D innovation policies (Heraud, 2003). For example, in the UK, the South East and East of England dominate R&D activities, together they account for 39% of total UK R&D expenditure (i.e. £11.9 billion) (ONS, 2014). In addition, among the European Union (EU) member states having the highest R&D intensities in 2014 were Finland (3.17%), Sweden (3.16%), Denmark (3.05%) and Austria (2.99%); while at least nine EU member states had R&D expenditure below 1.00 % of their GDP in the same year (Eurostat, 2016). Logically, it is safe to assume that in the long run, the poorer regions will continue to lag behind in terms of innovation capacities, leading possibly to a technology poverty trap (Heraud, 2003); therefore, one cannot expect that the same innovation development model used in regions where there are strong scientific institutions be as effective when utilized in regions (industrialized or not) having a low density of specialized technological institutions (Heraud, 2003). Due to this, solutions for theoretical and empirical issues regarding policy options that consider the needs and structure

of every region are necessary (Breschi & Lissoni, 2001b; Heraud, 2003).

The purpose of this paper is to investigate whether there are knowledge spill-over mechanisms that influence the growth performance of technology-based small firms in non-clustered regions. First, a review of literature and previous evidence on knowledge spill-overs and small firm performance was carried-out as will be explained in section 1.2 with new research issues being highlighted. Following that, theoretical distinction was made between clustered and non-clustered regions as expounded in section 1.3, and hypotheses on knowledge spill-over mechanism important for small firms in non-clustered regions were drawn in and presented in section 1.4. Lastly, section 1.5 presents the model on which the study was based. The study's methodology, results, discussion, and conclusion are presented in the succeeding sections.

1.2. Knowledge Spill-overs and Small Firm Performance in Clusters: Theory, Previous Evidence and New Research Issues

The simple but powerful idea that innovative technology-based small firms are concentrated in a minority of regions due to knowledge spill-overs is by no means an entirely new phenomenon. As far back as 1890, Sir Alfred Marshall described cities as "having ideas in the air" (1890; 1920). According to Maskell and Malmberg (1999), the historical development of the idea of knowledge spill-overs can be seen in the following studies by: Pred (1966) describing the role of information in urbanization economies; Hagerstrand (1967) explaining space in innovation diffusion; and Utterback (1974) illustrating innovation in industry and diffusion of technology. The need for scientific investigation of the confluence of geography and innovation has had a long history. More recently, it had manifested itself in the *Localized Knowledge Spill-over Theory* (Feldman & Florida, 1994; Zucker et al., 1998; Agrawal, 2001; Acs, 2002; Audretsch & Lehman, 2005a, b; Audretsch & Dohse, 2007; Raspe & van Oort, 2008; Maine et al., 2010; Goetz et al., 2016; Ghio, et al., 2016; Lapple et al., 2016; Isaksson et al., 2016). According to Breschi and Lissoni (2001a: p.258), localized knowledge spillovers can be broken down into three logical chains:

a. knowledge generated within innovative firms and/or universities is somehow transmitted to other firms;
b. knowledge that spills over is a (pure) public good, i.e., it is "freely" available to those who wish to invest in the search for it (non-excludability), and may be utilized by more than a few users at the same time (non-rivalry);
c. Despite b., knowledge that spills over is mainly "tacit", i.e., highly contextual and difficult to codify; therefore it is better transmitted through face-to-face contacts and personal relationships, which require spatial proximity; in other words, it is a public good, but a local one.

Scholars of local knowledge spill-overs argue that local knowledge spill-overs are the main reason for the innovative performance of small and medium sized enterprises (SMEs) especially in clusters (Saxenian, 1994; Zucker et al., 1998; Keeble et al, 1999; Acs, 2002; Stuart & Sorenson, 2003; Ghio et al., 2016). There are a variety of reasons that explain why knowledge spill-overs play a crucial role in influencing the performance of small firms in clusters. Marshall (1890) argued that a firm located within a region with high concentration of economic activities can influence higher firm efficiencies. He identified three key benefits that can accrue to firms located in clusters, which are: (1) labor market pooling; (2) accessibility to non-traded inputs, or the development of specialized intermediate goods; (3) and knowledge spill-overs. Today, localized knowledge spill-overs have become the most popular in empirical studies (see Feldman 1999 as an example).

In this context, one of the key conclusions of the knowledge spill-over literature is that firms in clusters using knowledge spill-overs will display greater rates of innovation (Jaffe, 1989; Acs, 2002; Ghio et al., 2016; Lapple et al., 2016; Isaksson et al., 2016) and higher rates of firm growth (Audretsch & Lehman, 2005a, b; Audretsch & Dohse, 2007; Raspe & van Oort, 2008; Maine et al., 2010; Goetz et al., 2016). This is because, as pointed out earlier, small firms have greater access to external knowledge resources and spill-overs due to proximity to social contacts in research institutions, and mobility of skilled labor from R&D intensive firms to small firms (Saxenian, 1994; Almeida & Kogut, 1999; Feldman, 1999; Acs, 2002; Ghio et al., 2016) despite having a disadvantage in performing in-house R&D which is crucial for innovation and growth when they are located within a cluster (Acs, 2002; Stam & Wennberg, 2009). This enable small firms to acquire the critical knowledge needed for innovation, which also influences their growth performance (Audretsch and Lehman, 2005a, b; Audretsch & Dohse, 2007; Raspe & van Oort, 2008; Stam & Wennberg, 2009; Maine et al., 2010; Goetz et al., 2016). The effect of innovations on growth is through the generation of new demand and/or the conquest of market shares at the expense of other firms and, consequently, the rise in the level of employment in firms (Niefert, 2006); thus, by acquiring knowledge and innovation, a firm can obtain temporary monopolistic profits until other firms are able to imitate the innovation or develop an even better one, thereby allowing the firm to grow (Niefert, 2006). At the firm level, Geroski and Machin (1992) observed that innovating firms are both more profitable and are able to grow faster than non-innovators. Roper (1997) studied 2,721 small businesses in the U.K., Ireland and Germany and found that innovative products, introduced by firms, made a positive contribution to growth. Freel (2000) considered 228 small UK manufacturing businesses and found that innovators are likely to grow rapidly. In addition, Stam and Wennberg (2009), using a data set of new firms, found empirical evidence on the impact of R&D on new product development, and on inter-firm alliances that give access to external knowledge and employment growth. At the regional level in the US for example, the employment growth rate in Silicon Valley cluster during the 1990s outperformed others with an impressive 15% of the U.S. national employment growth rate, with a mean income of 50% higher than the national figure (Audretsch, 1998). Moreover, in the beginning of the millennium, the Cambridge sub-region, characterized by having a large number of innovative small firms, increased the number of available jobs by 80% in comparison to UK jobs, which only grew by 16% (Barrell, 2004). This shows that a large body of evidence suggests that innovative firms have higher tendency to grow (Feeser & Willard, 1990; Niefert, 2006; Coad & Rao, 2008).

Accordingly, there is a fast growing literature on the influence of knowledge spill-overs on small firm performance particularly in clustered regions (Audretsch & Lehman, 2005a, b; Audretsch & Dohse, 2007; Raspe & van Oort, 2008; Chyi et al., 2012). In general, the findings (see Table 1) suggest that firm performance, as measured by employment growth, sales growth and productivity performance, is influenced by knowledge spill-overs (Audretsch & Lehman, 2005a, b; Audretsch & Dohse, 2007; Raspe & van Oort, 2008; O'Mahony & Vecchi, 2009; Chyi et al., 2012). Only very few studies, i.e. Dumais (2002), have found negative results; therefore, when taken together, the findings in the literature strongly suggest that localized knowledge spill-over inputs have a significant positive influence on small firm performance. Although the above studies took some time in understanding the role of knowledge spill-overs in generating superior small firm performance, the question of whether or not knowledge spill-overs matter for small firm performance in non-clustered

regions has remained largely unexplored. This is partly caused by the assumption that 'all' external knowledge flows influencing firm performance are 'local' (Simmie, 2002, 2003; Breschi & Lissoni 2001a, b). It is certainly inconceivable that all of the knowledge flows required for innovation by all the firms in the region will be found within the local environment even in technologically advanced clusters (Breschi & Lissoni, 2001a, b; Simmie, 2002); thus, considering that knowledge flows can occur not only at the local but also at the national and international levels (Simmie, 2002), implies that even firms in non-clustered regions may benefit from national and international knowledge flows even if they lack local flows (Breschi & Lissoni, 2001a, b). This further strengthen the need to investigate the importance of knowledge spill-over mechanisms for small firm performance in non-clustered regions, and whether they are inherently different from those influencing small firm growth in clustered regions.

Table 1: Contributions to Localised Knowledge Spill-overs and Firm Performance

Author(s)	Sector/Space/Method	Cluster/Knowledge Spill-over Measure	Firm Performance	Gaps/ Weaknesses
Goetz et al. (2016)	Space: US	Establishments and higher educational attainment	+(Sales performance)	2
Choi and Williams (2014)	Space: China	Knowledge spillovers from technological neighbours	+(Sales growth)	1,2
Tambe and Hitt (2013)	Space: US	IT investments from other firms	+(Productivity growth)	1,2
Chyi et al. (2012)	Space: Hsinchu Science Park (HSP). The Taiwan	External R&D spillover	+(Sales growth)	1,2
O'Mahony and Vecchi (2009)	Space: US, Germany, France and UK	R&D and skill intensive industries	+(Productivity performance)	1,2
Raspe and van Oort (2008)	Space: Regions in Netherlands	• Knowledge workers • Innovation • R&D	+ (Employment growth)	1,2
Audretsch and Dohse (2007)	Space: Germany	• Proximity to university • Agglomeration	+ (Employment growth)	1,2
Audretsch and Lehman (2005b)	Space: Germany	• Proximity to technical and general universities	+ (Employment growth)	1,2
Globerman et al. (2005)	Space: (1) 11 provinces, (2) 10 metropolitan areas, (3) distance to the two largest clusters	• No agglomeration measure • compares outcome for each region)	+ (Sales growth)	1,2
Audretsch and Lehman (2005a)	Space: Germany	• Proximity to university	+ (Employment growth)	1,2
Dumais et al. (2002)	Space: 50 US States plus District of Columbia	• Industry concentration based on employees in 3-digit SIC industries	- (Employment growth)	1,2
Baptista and Swann (1999)	Space: 39 US states, 10 UK Central Statistical Office regions	• Employee count	+ (Employment growth)	1,2

1. Does not examine knowledge spillover mechanisms that matter for small firm growth in non-clustered regions.
2. Does not investigate the specific role of imitation spillovers in enhancing the performance of small firms in non-clustered regions

1.3. Distinction between Clustered and Non-clustered Regions

This study defined "cluster" using Porter's (1998: p. 199) definition as a "geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities". The "companies" in the definition can be further expounded to related industries and associated institutions such as research-intensive universities and public research institutions in a particular field. Briefly, the key features of high-technology clusters are discussed below:

- *Universities/Public Research Institutions:* The literature on knowledge spill-overs argued that one of the reasons why regions have different rates of small firm performance is because of university R&D and its associated spill-overs in terms of new business formation and influences on performance of proximate firms (Jaffe, 1989; Zucker et al., 1998; Acs, 2002; Audretsch et al., 2005; Audretsch & Lehman, 2005a, b; Audretsch & Dohse, 2007; Maine et al., 2010). Jaffe (1989) argued that this is because the pools of talented graduates, the ideas generated by faculty and the high-quality libraries and other resources of research universities, often have positive spill-overs in their neighborhoods; thus, any region with limited university research or other research intensive organizations will be lacking an important feature of high-tech clusters, as they are less likely to benefit from university spill-overs (Acs, 2002; Stuart & Sorenson, 2003; see Figure 1).
- *Workforce Density:* Previous studies have proven that this is an important feature of clustered regions (Lublinski, 2003; Atherton & Johnston, 2005). As Figure 1 suggests, regional clusters have a critical mass with high densities of workforce in similar high-technology regions (Audretsch, 1998; Lublinski, 2003). This clustering of people in related high-technology sectors, within physical space, often facilitates informal social and professional networks that may influence the development of innovation and firm performance (Saxenian, 1994; Sorenson & Stuart, 2003; Audretsch & Lehman, 2005a, b; Audretsch & Dohse, 2007; Goetz et al., 2016). Subsequently, workforce density is considered an important feature of clusters that generates spill-overs; and any region lacking such a characteristic may best be referred to as having low or non-clustered (Suarez-Villa & Walford, 1997; Lublinski, 2003: see Figure 2).

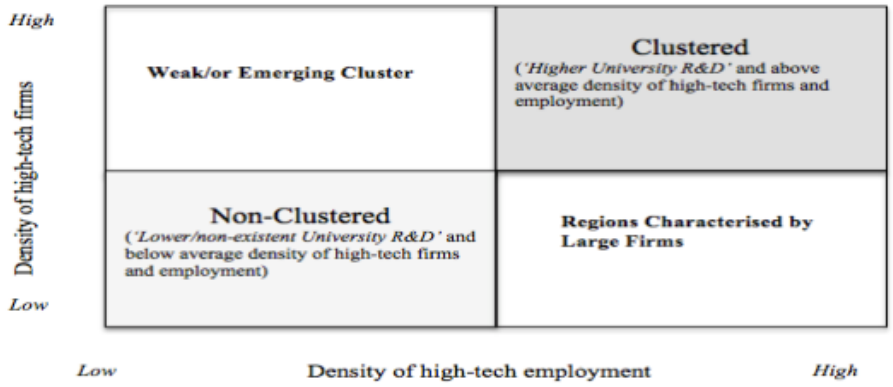


Figure 1: Technology-based Clustered and Non-clustered Regions

Sources: Saxenian (1994); Audretsch, 1998); Acs (2002); Lublinski (2003), Atherton and Johnston (2005)

- *Firm Density:* Similar to workforce density, this is another important feature of clusters. Firm density provides an indication of the likelihood of localization of knowledge where firm densities are high rather than in areas where firm densities are low (Almeida & Kogut, 1999). Each of the many firms that constitute the population tend to specialize in just one phase, or a few phases of the production processes, typical of the location, thereby giving rise to collaborative practices, spin-offs, outsourcing and other forms of inter-firm networks (Angel, 1989; Saxenian, 1994; Sorenson & Stuart, 2003); thus, while clustered firms tend to benefit from local networks, non-clustered firms are less likely to benefit from dense local networks, often due to dearth of proximity to other high-tech firms (Saxenian, 1994; Stuart & Sorenson, 2003; Audretsch & Lehman, 2005b; Myint, Vyakarnam & New, 2005). In general, the above discussion outlines some of the key features of clusters that give rise to knowledge spillovers, through mechanisms, such as: (1) university/public research spill-overs (Acs, 2002; Audretsch & Lehman, 2005a, b; Audretsch & Dohse, 2007; Ghio et al., 2016); (2) labor mobility spill-overs (Saxenian, 1994; Almeida & Kogut, 1999); (3) personal networks with employees of other firms (Saxenian, 1994; Stuart & Sorenson, 2003).

The problem with the abovementioned mechanisms of knowledge spill-overs for non-clustered firms is that they are mechanisms that require high levels of research by public institutions and local clustering to influence small firm performance (Saxenian, 1994; Audretsch & Lehman, 2005a, b; Audretsch & Dohse, 2007; Maine et al., 2010; Ghio et al., 2016). A number of researchers suggest that there are critical differences between clustered and non-clustered firms in sourcing knowledge that drive innovation. The following are the examples:

- Basant et al. (2011) found that although both international customer networks and other local networks influence capability formation of firms in clusters, national customer capital enable knowledge transfer to firms in non-clusters;
- Ibrahim and Fallah (2005) showed that firms in clusters are more likely to use the collective local tacit knowledge and local knowledge spill-overs within clusters; but there is no significant difference for data related to the corporate sources of knowledge (knowledge from inside the company) between clustered and non-clustered firms;
- Doloreux and Shearmur (2006) found that non-clustered regions are not equipped to offer the volume and frequency of interaction for knowledge and therefore, have to interact with other regions to allow a non-cluster to function;
- Bagchi-Sen (2004) suggested that university scientists are important and the key purpose of interacting with them for cluster firms is to access basic research. In contrast, one of the main reasons of such interaction for non-clustered firm is product development;
- Lublinski (2003) found that non-clustered firms consider competition with distant firms more important.

One common finding among these examples is that non-local sources of knowledge (Lublinski, 2003; Doloreux & Shearmur, 2006; Basant et al., 2011) that require basic research (Bagchi-Sen, 2004) serve as crucial sources of knowledge e.g.

from competitors for non-clustered firms. This suggests that the imitation of non-local firms serve as an important mechanism of knowledge acquisition for non-clustered firms; however, in relation to our research problem, previous studies have not investigated whether or not imitation of non-local firms matter for SME growth performance. The role of technology imitation in the growth performance of non-clustered SMEs will be critically discussed and developed in the next sections.

1.4. Technology Imitation Spill-overs: Hypothesis on the Influence on Small Firm Growth in Non-clustered Regions

Studies on knowledge spill-overs and clusters suggest that the most important knowledge spill-over mechanisms such as university spill-overs and labor mobility are highly local (Angel, 1989; Saxenian, 1994; Audretsch, 1998; Acs, 2002); conversely, as suggested by Breschi and Lissoni (2001b) and Kim (1997, 1999, 2001), a number of other important mechanisms by which firms learn 'secrets' of competitors are not sensitive to geographic distance e.g. reverse engineering. Due to an overwhelming focus on clusters, the importance of imitation through reverse engineering has been overlooked by literatures on knowledge spill-overs (Breschi & Lissoni, 2001b). In this context, some inspiration can be drawn from the technological capability literature in developing countries with regards to the role of imitation through reverse engineering for enhancing performance of technologically lagging regions. The technological capability literature suggests that firms in developing countries, despite having an initial state of low R&D, still manage to develop innovation capabilities through a specific spill-over mechanism which is imitation through reverse engineering (Kim, 1980, 1997, 1999; Glass 2010). Reverse engineering can be defined as the process of discovering the technological principles of a device, object, or system through analysis of its structure, function, and operation (Eilam & Chikofski, 2007). It usually involves taking something (e.g., electronic component) apart to analyze its workings in greater detail, often, for the purpose of creating a new device or program that does the same thing (Eilam & Chikofski, 2007). For many former developing countries, the initial phases of high imitation and weak intellectual property rights (IPRs) provided the possibility to adopt foreign technologies and gain valuable experience from reverse engineering (Newiak, 2011). In Japan for example, weak IPR protection was selected as an instrument to ease the adoption of foreign technologies in order to develop a domestic R&D sector (Newiak, 2011); hence, the barring of some products such as pharmaceutical and food products from patenting created an atmosphere of weak protection for foreign innovators, but facilitated domestic firms in acquiring foreign knowledge through imitation (Kumar, 2003). Consequently, imitation can be a "stepping stone to innovation" (Glass, 2010). Accordingly, Kim (1999) developed one of the most authoritative firm level models that identified the mechanisms through which firms in developing countries can raise their existing knowledge base through market and non-market mediated mechanisms that fundamentally rely on foreign technology. These mechanisms are as follows:

- *Market mediated mechanisms*: Formal technology transfer through technology licensing and contract research, are some of the key sources of market-mediated mechanisms; however, these sources are more relevant when industrialization progresses in developing countries (Kim, 1999; Isaksson et al., 2016).
- *Non-Market mediated mechanisms*: Informal transfer of knowledge through imitation of foreign technology particularly through reverse engineering is viewed as a crucial informal source of new knowledge for firms in developing countries (Kim, 1999).

Based on several analyses made during the rise of the East-Asian countries against developed innovator countries, among the above mechanisms, imitation through reverse engineering is one of the most crucial sources of knowledge that can help spur original innovation and performance in emerging countries (Kim, 1980, 1997, 1999, 2001; Glass 2010). This is because the larger the knowledge gap, the easier imitation is due to the larger pool of potential imitations (larger world knowledge stock); but when knowledge gap is reduced with successive imitations, imitation then becomes somewhat more difficult and innovation becomes more attractive (van Elkan, 1996). Performance is therefore, characterized by an initial period of rapid imitation, for which there exists a large catch-up opportunity, followed by a shift towards innovation as the knowledge gap is reduced (van Elkan, 1996). Interestingly, although they cannot be equated, technology firms in a developing country during the initial stage of catch-up and non-clustered firms (of a developed country) share some striking similarities in that they both are in technologically lagging regions (Kim, 1999; Heraud, 2003) and are characterized by low levels of regional stock of knowledge (Mishra, 1997; Kim, 1997; Wong, 1999; World Bank, 2000; Kim, 2001; Acs, 2002; Abubakar & Mitra, 2007). In this context, considering that small firms in non-clustered regions, even in a developed country have lower access to R&D compared to cluster firms, (Florida & Kenney, 1988; Acs, 2002; Abubakar & Mitra, 2007) are more disadvantaged in terms of benefiting from university spill-overs and other critical sources of knowledge that require proximity (Angel, 1989; Saxenian, 1994; Acs, 2002; Stuart & Sorenson, 2003; Lapple et al., 2016), and that firms that have low initial state of R&D in developing countries often build their capabilities through imitation (Kim, 1999, 2001). Consequently, it seems logical to suggest that such firms in non-clustered regions of a developed country will primarily resort to informal sources of acquiring technology such as imitation as a way of boosting their technological capability and performance.

Non-clustered regions have a high imitation opportunity from national sources and abroad despite the lack of local stock of knowledge. Imitation attempt is specifically expected to influence employment growth of small firms in non-clustered regions because imitation firms often have to hire workers who engage in reverse engineering (Newiak, 2011). This yields the following hypothesis:

H1: In non-clustered regions, the growth performance of technology-based small firms is likely to be positively influenced by 'imitation of non-local firms through reverse engineering'.

H2: In clustered regions, the growth performance of technology-based small firms is 'not' likely to be positively influenced by 'imitation of non-local firms through reverse engineering' (since growth performance in such regions is more likely to rely on research intensive sources like university spill-overs).

5. The Model: Knowledge Spill-overs and Small Firm Growth

The conceptual framework for analyzing the impact of knowledge spill-overs on firm growth is based on the most commonly used model for examining the impact of external knowledge on growth at the firm level (see also Audretsch & Lehman, 2005, 2007; Audretsch & Dohse, 2007; Raspe & van Oort, 2008; Maine et al., 2010). The model is based on the groundbreaking works by Hall (1987) and Evans (1987), who developed an empirical growth equation for examining the hypothesis that the individual characteristics of a firm, e.g. size and age, have an influence on firm growth (Audretsch & Lehman, 2005, 2007; Audretsch & Dohse, 2007; Raspe & van Oort, 2008; Coad, 2008). This is presented below:

$$GROWTH_{i,t} = B_0 + B_1 (Size_{i,t-1}) + B_2 (Size_{i,t-1})^2 + B_3 (Age_{i,t-1}) + \varepsilon_{i,t,} \quad (1)$$

The influence of initial size on the consequent rate of a firm's growth is represented by B1. If B1 = 0 then the growth of a firm is independent of the initial firm size, thereby giving support to Gibrat's law of proportionate effect[1]. Gibrat's law states that the size of a firm and its growth rate are independent of each other. This means that firm growth is viewed mainly as a stochastic phenomenon that occurs as a result of chance operation of a number of factors acting on each other; however, B1 < 0 suggests that small firms tend to grow at a faster rate than larger firms. On the other hand, B1 > 0 implies that larger firms grow at a faster rate than smaller firms. Subsequently, firm growth for firm i in period t is presented as a function of initial firm size, size2, the firm's age, and also a stochastic error term εi, t. There is a very large body of empirical evidence estimating equation (1) (see Sutton, 1997 and Caves, 1998 for a survey). The analysis is typically carried-out at the firm level and is therefore a firm specific model (Audretsch & Lehman, 2005, 2007; Audretsch & Dohse, 2007; Raspe & van Oort, 2008; Coad, 2008). The evidence suggests that both size and age are negatively related with the growth of firm.

Audretsch and Lehman (2005a, b) extended the traditional firm-specific model by including external knowledge factors affecting firm growth since equation (1) mainly focuses on firm-specific characteristics. They did this by including measures that reflect 'external knowledge' basing on the work of Carlton (1983), Bartik (1989), and Reynolds et al. (1994), which are measures that reflect the importance of external knowledge and technology, referred to as knowledge spillovers, that may impact on firm growth (Audretsch & Lehman, 2005a, b; Audretsch & Dohse, 2007). The basic model is presented as follows:

$$GROWTH_{i,t} = B_0 + B_1 (Size_{i,t-1}) + B_2 (Size_{i,t-1})^2 + B_3 (Age_{i,t-1}) + B_4 (Knowledge_{r,t-1}) + B_5 (X_{r,t-1}) + \varepsilon_{i,t}, \quad (2)$$

In equation (2), the external knowledge, i.e. knowledge spill-overs, is represented by $Knowledge_{r,t-1}$, and $X_{r,t-1}$, represents a vector of other regional variables that have been hypothesized to have an impact on firm performance such as technology licensing, which is a market-mediated factor (Kim, 1999; Breschi & Lissoni, 201a, b). This equation suggests that firm performance is influenced by a knowledge spill-over that is often region-specific (Audretsch & Lehman, 2005a, b; Audretsch & Dohse, 2007). In this context, if knowledge spill-overs have no role in enhancing firm growth, the coefficients of external knowledge variables will be zero. Conversely, if the growth of a firm is enhanced by external knowledge factors, then the coefficients will not equal to zero. More specifically, if knowledge spill-overs influence firm growth, then the resulting effect is that the coefficients will be greater than zero. In other words, positive coefficients on knowledge measures will imply that the growth of a firm is positively and systematically influenced by firm's use of external knowledge.

The framework expressed in equation (2) has become the foundation for several empirical investigations (Audretsch & Lehman, 2005a, b; Audretsch & Dohse, 2007; Raspe & van Oort, 2008; Maine et al., 2010). This paper extends previous evidence by examining the influence of external knowledge, i.e. $Knowledge_{rt-1}$ in equation (2) (Audretsch & Lehman, 2005a, b; Audretsch & Dohse, 2007; Raspe & van Oort, 2008), acquired from imitation spill-overs (Kim, 1999, 2001) on small firm growth in non-clustered regions.

[1] It is argued by Tschoegel (1983) that for Gibrat's law to stand in a robust way, growth should not continue from one period to the next and that the variability of growth is independent of firm size.

2. Methodology

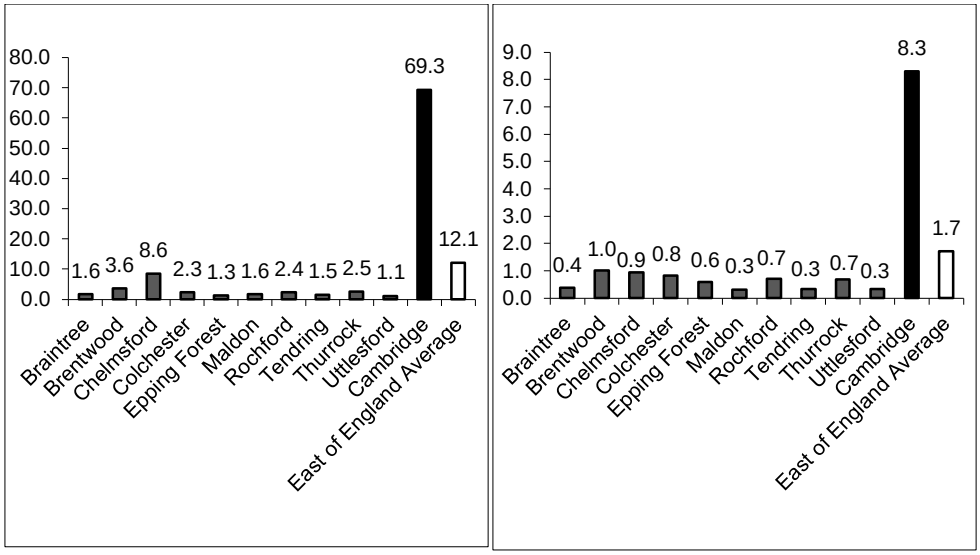
2.1 The Setting: Clustered and Non-clustered Small Firms in the East of England Electronics and Computer Industries

This research is based on a survey of clustered and non-clustered technology-based small firms in the East of England. The clustered firms were categorized as the control group. The samples of the study were taken from East of England due to significant differences in clustering of technology-based industries in its regions. In a report entitled *The East of England in the Knowledge Economy* by Hutton and Williams (2006: p.3) observed that the East of England is unique; the economies of its six sub-regions are miles apart (i.e. Essex, Norfolk, Suffolk, Cambridgeshire, Bedfordshire and Hertfordshire). The share of knowledge jobs differs from 62 percent in Cambridge to approximately 20 per cent in some of the other areas. About six percent of the knowledge jobs in the East of England are in Cambridge.

The agglomeration of electronic and computer-related high-technology industries was calculated for each local authority in the East of England to identify the areas with clustered and non-clustered firms. As discussed earlier, this was done because an extensive body of scholars agrees that the geographic agglomeration of *firms* and *workforce* in a particular sector is one of the defining features of regional clusters (Saxenian, 1994; Audretsch, 1998; Manimala, 2006). Clustered and non-clustered areas in the East of England were identified by mapping the locations of agglomerated firms and workforce in the high-tech electronics and computer-related sectors. The sector selection was based on the nine 4-digit Standard Industrial Classification (SIC) categories identified by Cambridge County Council (CCC, 2004: p.65-66). These categories corresponded to two main groups: (1) high-tech electronic sectors (3002; 3130; 3220; 3210; 3230; 3310; 3320; 3330; 3340) and (2) computer-related sectors (7210; 7221; 7222). The data was sourced from the *Annual Business Inquiry Workplace Analysis* (Office for National Statistics, 2007).

Next, in order to map out the local authority areas with clustered and non-clustered firms in high-tech electronic and computer-related sectors, the firm density was calculated by dividing the number of firm workplaces for every square kilometer (km^2); and workforce density by dividing the number of workers for every square kilometer ($km^{2)}$. The areas with high workforce density and firm workplace density were considered highly clustered, while those with low scores were considered as non-clustered. This approach of classifying clustered and non-clustered firms was similar to that used by Suarez-Villa and Walrod, (1997) and Lublinski (2003). The correlation between workforce density and firm workplace density as the two measures of clustering was 0.86; which indicates that the two measures are highly related.

The mapping of the firms in high-tech electronic and computer-related sectors led to Cambridge (in Cambridgeshire) being identified as having very high clustering of workforce and firms among the high-tech sectors; this is mainly because of the Cambridge Silicon Fen cluster (Keeble et al., 1999; Myint et al., 2005). The Cambridge area has a density of 69.3 workforce per km^2 and 8.3 firm workplace per km^2 , which was the highest (see Figure 2a and b); thus, firms belonging in the Cambridge Silicon Fen cluster were considered as clustered Firms. In contrast, 10 other local authorities in the East of England were identified as having low densities of both workplaces and workforce in both sectors; and were designated as non-clustered regions (see Figure 2a, b; Figure 3a, b). These areas are Braintree, Brentwood, Chelmsford, Colchester, Epping Forest, Maldon, Rochford, Tendring, Thurrock and Uttlesford (all in Essex county of East of England).



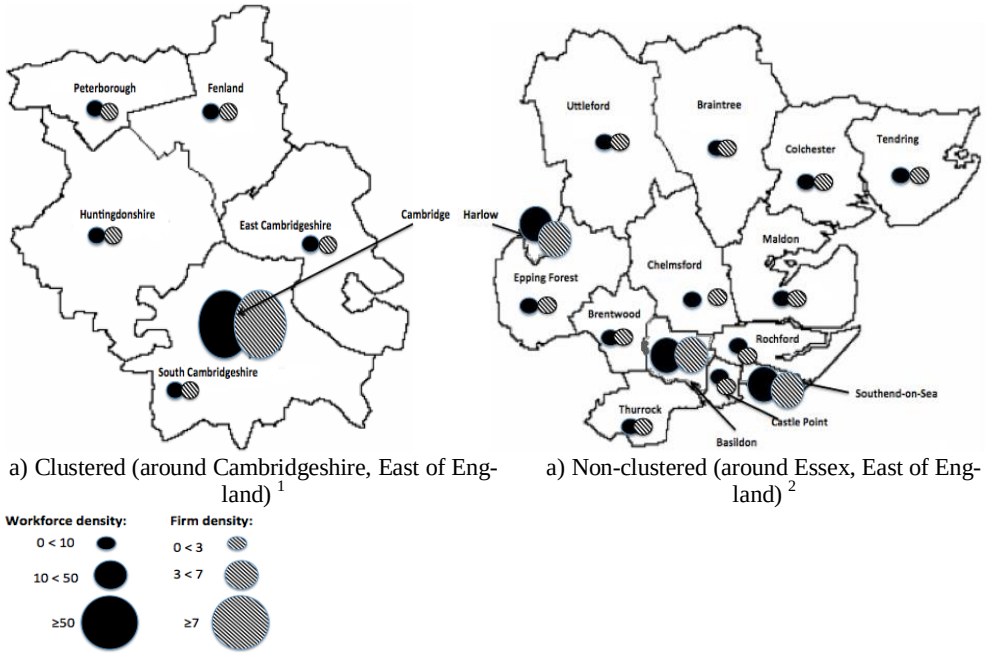
a) Workforce Density(Workforce/Km2) b) Firm Density (Firm Workplace/Km2)

Figure 1: East of England: Location of Clustered and Non-clustered Firms

Note: All estimates are for firms in high-tech electronic (3002; 3130; 3220; 3210; 3230; 3310; 3320; 3330; 3340) and computer-related (7210, 7221,7222) sectors.
Source: Author's survey based on Annual Business Inquiry Workplace Analysis data from NOMIS (2007)

The above calculations relate strongly to the data on clustering and knowledge intensive activities provided by Essex Country Council (2006), which further reinforce the fact that Cambridgeshire, the county where Cambridge is located, is highly clustered; while the county where the 10 non-clustered areas are located i.e. Essex, lack clustering. The Essex Country Council (2006) data suggests that Cambridgeshire has a massive proportion of employees in specialized and 'knowledge intensive sectors' with 11%; in contrast to Essex which has a corresponding figure of only 1% (Essex County Council 2006; see Table 2). This is further supported by other papers that identified Cambridge as a cluster (Casper & Karamanos, 2003; Myint et al., 2005; Huber, 2012a, b).

Therefore, the Annual Business Inquiry Workplace Analysis data from NOMIS (2007) and the Essex County Council (2004) provided the basis for the selection of high-tech electronic and computer sector related firms in Cambridge as being *Clustered Firms*, and those in Braintree, Brentwood, Chelmsford, Colchester, Epping Forest, Maldon, Rochford, Tendring, Thurrock and Uttlesford as being *Non-Clustered Firms* in the East of England.



a) Clustered (around Cambridgeshire, East of England) [1]

a) Non-clustered (around Essex, East of England) [2]

Figure 2: Map of the Regions of East of England

1. Cambridge in Cambridgeshire, East of England.
2. Braintree, Brentwood, Chelmsford, Colchester, Epping Forest, Maldon, Rochford, Tendring, Thurrock and Uttlesford in Essex, East of England.

Source: Author's survey based Annual Business Inquiry Workplace Analysis data from NOMIS (2007)

Table 1: Key Regional Economy and Clustering Indicators

Indicators		Cambs	Essex
Economy	GVA per resident	£17,631	£13,631
	GVA per local job	£32,404	£29,786
Higher Education & R&D	Population qualified to NVQ 4+	27%	17.4%
	University R&D	£150million	£10million
Clustering	Employees in specialised and 'Knowledge intensive sectors'	11%	1%
	Proportion of local employees in highly clustered sectors	6%	1%
	ICT start-ups per 10,000 population	4.15	1.82

Sources: Annual Business Inquiry (2004), Arthur D. Little (2003), Abubakar and Mitra (2007)

2.2 Survey Data and Measures

Participants from high-tech electronic and computer-related sectors in the identified clustered and non-clustered areas in East of England were randomly selected. Data collection was done through administration of a survey. In addition, a common questionnaire was designed to collect data for the years 2004-2007 in order to facilitate comparison among small firms in the contrasting regions. The samples were drawn from some of the most authoritative

directories for identifying high-tech firms which include: Cambridge Networks Directory, Apple Gate Directory, Essex ICT Directory and Yell.com, which provide industrial specialization of firms. Only firms that fit the following criteria were sampled: (1) firms with less than 250 employees to ensure that only SMEs are selected (European Commission, 2002); (2) firms belonging to high-tech electronic and computer-related sectors (CCC, 2004) to ensure that firms are selected from high-tech sectors with relatively high innovative activities, especially for small firms (Acs & Audretsch, 1988; Novalis Research, 2004); (3) firms must be located in the identified clustered and non-clustered areas of East of England Firms that qualified under the criteria were randomly selected resulting to 235 firms in the clustered region and 207 in the non-clustered areas. The response rate for the clustered and non-clustered regions was 22% and 23% respectively. This sample is considered representative of the target population having a fairly good response rate, even higher than some of the leading surveys on regional clusters (Suarez-Villa & Walrod, 1997; Keeble et al., 1998; Athreye, 2001). For instance, the study by Suarez-Villa and Walrod (1997) which looked at both clustered and non-clustered firms in the high-tech electronics sector of Los Angeles Basin, USA, only had a response rate of 4% from the 76 establishments surveyed. Similarly, the well-known Survey of Cambridge firms (known as CBR Survey) by Centre for Business Research (CBR) at the University of Cambridge, which is used by authorities on geography and innovation (Keeble & Lawson, 1998; Athreye, 2004), was based on only 50 firms, even though their target population was all of the technology firms in Cambridge Silicon-Fen (i.e. all sectors, not just electronic and computer related sectors, but also biotechnology etc.), which in 1999, numbered up to 959 (Athreye, 2004). The response rate of the CBR survey was only approximately 10%. The present paper's survey only had a small difference between the number of clustered and non-clustered firms in the sample with a high response rate of 22% and 23% respectively; thus, making the samples even more comparable (Bryman & Bell, 2003). The survey questionnaire was designed to gather information from firms regarding their innovative activities and knowledge spillovers mechanisms.

2.2.1 Dependent Variable

2.2.1.1 Firm Employment Growth

Firm level employment growth (*GROWTH*) is measured using the following formula taken from by the European Commission (2002):

$$\underset{rate}{standard\ growth} = \frac{(\text{employment year 2}) - (\text{employment year 1}}{(\text{employment year 1})}$$

The year 2004 was taken as the base year, while 2007 as the current year. The standard growth rate is commonly used in firm growth (European Commission, 2002).

2.2.2 Independent Variables

2.2.2.1 Firm Specific Variables

The growth of a firm as discussed earlier is influenced by firm specific factors which are age and size (Sutton, 1997, Caves, 1998; Audretsch & Lehman, 2005a, b; Audretsch & Dohse, 2007). The first variable, firm age (*AGE*), is measured in years starting from the firm's founding; while the second variable, firm size (*SIZE*), is measured by the number of employees during the base year of the study i.e. 2004.

2.2.2.2 Knowledge Spill-overs

The questionnaire was designed to measure the importance of various knowledge spill-over mechanisms from local, national and international sources. For each case, the respondents were required to record the importance of various local, national and international knowledge sources for innovative activities. This enabled the researchers to capture the opinion of small firms which reflected their strategic use of external knowledge. The ap-

proach was developed based on major innovation studies i.e. The Oslo Manual (OECD/EC/Eurostat, 1997) and Community Innovation Survey 3 (CIS, 2004).

In the literature, some of the most cited knowledge spill-over mechanisms include: research institutes e.g. university spill-overs, labor mobility, personal networks, publications, imitation, patent disclosures and conferences (Saxenian, 1994; Almeida & Kogut, 1999; Liebeskind et al., 1996; Kim, 1999, 2001; Stuart & Sorenson, 2003; Audretsch, 2003; Audretsch & Lehman, 2005a, b; Audretsch & Dohse, 2007). The 9 indicators for knowledge spill-over mechanisms cited in the literature on were each measured at the local, national and international levels (Breschi & Lissoni, 2001a, b; Simmie, 2002; see Appendix A). Subsequently, a principal component factor analysis of the indicators used based on the above listed mechanisms on knowledge a spill-over was conducted. The rationale for using factor analysis was to simplify the knowledge spill-over variables from the questionnaire into fewer meaningful factors, since the variables collected through the questionnaire were simply indicators of underlying factors, and were therefore, strongly correlated. For example, firms with strong use of university spill-overs may also use spill-overs from public research organizations (Saxenian, 1994; Stuart & Sorenson, 2003). Direct inclusion of the indicators would result in multi-collinearity. The principal component factor analysis yielded six factors on knowledge spill-overs. These were significant and meaningful, accounting for the 72.2% of the total sample variance that can be readily interpreted in accordance with the knowledge spill-over mechanisms identified in the literature (Saxenian, 1994; Almeida & Kogut, 1999; Liebeskind et al., 1996; Stuart & Sorenson, 2003; Audretsch, 2003; Audretsch & Lehman, 2005a, b; Audretsch & Dohse, 2007). The six factors can be interpreted as: (1) university/public institute spill-overs (*University/Public Institute*), (2) spill-overs from conferences /associations (*Conferences/Associations*), (3) spill-overs from personal contacts (*Personal Contacts*), (4) labor mobility (*Labor Mobility*), (5) imitation of non-local firms through reverse engineering (*Imitation of Non-Local Firms)* and (*International Spill-overs*), (6) international spillovers.

Factor 1: University/Public Institute Spill-overs

This factor is made up of variables that mainly relate to the acquisition of free knowledge from research institutions e.g. colleges and universities. Spill-overs from such research institutions are commonly discussed in the literature (Audretsch, et al., 2012; Fukugawa, 2013). Previous studies on clusters in US and Germany have tested and argued that spill-overs from universities can boost local innovation and firm growth performance (see Acs, 2002; Audretsch & Lehman, 2005a, b; Audretsch & Dohse, 2007); however, such studies did not compare clustered with non-clustered SMEs.

Factor 2: Spill-overs from conferences/Associations:

These are variables that are related to trade associations and conferences. As demonstrated by previous studies, informal communications through discussions by innovation actors at engineering and scientific conferences were also considered important mechanisms of knowledge spill-overs (see Monjon & Waelbroeck, 2003); then again, these studies did not compare the influence of spill-overs from conferences/associations on SME growth in clustered and non-clustered regions.

Factor 3: Personal Contacts

Variables belonging to these factors are related to the acquisition of free knowledge through personal contacts. Knowledge spill-overs from personal contacts have been discussed and investigated particularly in clustered regions (e.g. see Saxenia, 1994; Dahl, 2004). The study by Saxenian (1994) and by Lissoni (2001) that analysed the Silicon Valley (USA) and the Brescia mechanical cluster respectively, found that clusters are comprised of per-

sonal networks of individual engineers connected by personal ties of reputation and trust; still, these studies did not consider non-clustered SMEs.

Factor 4: Imitation of non-local firms

This factor is made up of 2 variables, which relate to reverse engineering the products of non-local competitors (Breschi & Lissoni, 2001b) as means to acquiring knowledge and ideas. There, it focuses on imitative technological learning, where firms learn through imitating other firms, and incrementally modify them into new products.

Factor 5: Imitation of Non-Local Firms through Reverse Engineering:

This factor involves variables related to the imitation of products of non-local firms as a source of spill-over. Although not much has been written about this in developed countries, scholars on newly industrialized countries such as Korea, Taiwan and Singapore, have long observed that imitation through reverse engineering has an important impact on firms (Mishra, 1997; Kim, 1997, 1999, 2001; Wong, 1999; World Bank, 2000). The question that remains therefore is whether or not it plays a significant role in influencing SME growth in clustered and non-clustered regions in developed countries.

Factor 6: International Spill-overs:

This factor consists of variables that are fundamentally about the use of international spill-overs via discussions with overseas employees of other SMEs, international trade associations, and the international mobility of labor. The importance of international spill-overs has long been discussed and tested (see Branstetter, 2001); however, its importance for SME growth in clustered and non-clustered regions has not yet been explored.

2.3 Validity, Reliability and Robustness

The two samples from which data was collected were randomly selected, and improving the study's external validity (Bryman & Bell, 2003). The construct validity was improved by developing measures based on well-acknowledged innovation and growth studies (European Commission, 2002; Community Innovation Survey 3, 2004; Audretsch & Lehman, 2005a, b; Audretsch & Dohse, 2007). Also, all factors derived from the factor analysis were tested for reliability using Cronbach's alpha and had an average score of 0.79 which can be considered reliable (Manimala, 1999; Schutte et al., 2000; Bryman & Bell, 2003). The study's robustness was examined in two ways: (1) by using split-sample validation, and (2) by examining the influence of knowledge spill-overs, specifically imitation spill-overs, on the capacity of small firms to generate technological innovation (since imitation spill-overs influence small firm growth in non-clustered region by enhancing their innovativeness).

2.4 Profile of Surveyed Firms

The literature stipulates that small firms in clusters will have higher access to scientific and engineering employees due to the advantages of clustering, in terms of access to a greater number of social and professional contacts. Those in non-clustered regions are likely to find it difficult to recruit scientific and engineering employees (Stuart & Sorenson, 2003). Accordingly, it was found that clustered firms have a significantly higher percentage of employees with a science and engineering background ($p<0.1$) in comparison to non-clustered small firms; the former having 65% while the latter at 27% reflecting their greater emphasis on in-house R&D (Table 3). There were no significant differences in terms of employees with degrees in other subjects ($p>0.1$). The descriptive statistics presented below also suggests that the clustered small firms have significantly higher levels of formal in-house R&D than the non-clustered small firms (Table 3). This is probably because regions with regional clusters of technology firms also have a higher concentration of financial institutions that support innovative activities (Florida & Kenney, 1988). Moreover, clustered firms on average, spend 32% of their turnover on R&D, while non-clustered firms only spend 11%;

this suggests that clustered firms have greater R&D activities in comparison to non-clustered firms (See Table 2).

Table 2: Descriptive Statistics

	Region	Mean	Std. Deviation	Sig. (2 tailed)
Number of founders	Clustered Firms	3.37	6.843	
	Non-clustered Firms	1.96	1.071	
Number of employees 2004	Clustered Firms	23.16	36.726	
	Non-clustered Firms	16.72	37.880	
Employees with science or engineering degree (%)	Clustered Firms	65.07	29.926	***
	Non-clustered Firms	26.93	34.640	
Employees with degrees in other subjects (%)	Clustered Firms	16.16	14.632	
	Non-clustered Firms	18.97	30.457	
Number of employees-2007	Clustered Firms	45.75	155.240	
	Non-clustered Firms	18.72	39.846	
Formal in-house R&D	Clustered Firms	3.83	1.629	***
	Non-clustered Firms	2.51	2.201	
Proportion of turnover spent on R&D	Clustered Firms	32.22	51.473	***
	Non-clustered Firms	11.70	16.134	
Other in-house technological activities	Clustered Firms	3.45	1.542	
	Non-clustered Firms	2.91	1.951	
Ideas generated from marketing etc.	Clustered Firms	3.45	1.757	
	Non-clustered Firms	2.96	1.821	
Number of patents	Clustered Firms	1.69	4.731	*
	Non-clustered Firms	.45	1.666	
Growth Rate (employment)	Clustered Firms	66.0084	164.27140	
	Non-clustered Firms	56.9613	219.79862	

*P≤0.1 (2-tailed); ** P≤0.05 (2-tailed); *** P≤0.01 (2-tailed);

There were no significant differences in growth rates of small firms within the two environments suggesting that non-clustered high-tech firms also experience high growth rates. The average growth rates during the 2004 – 2007 period was 66% and 57% for the clustered and non-clustered firms respectively.

In summary, the descriptive data presented here appears to be somewhat in line with what is known already in the knowledge spill-over literature, in that firms in clusters are likely to have advantages in R&D and innovative activities (Jaffe, 1989, Audretsch, 1998; Acs, 2002; Stuart & Sorenson, 2003); however, when it comes to growth rates, it certainly seems thought-provoking that the non-clustered, technology-based small firms also experience considerably high rates of growth despite being characterized as having lower rates of traditional sources of firm growth, such as in-house R&D and innovation activities. This makes the analysis of external sources of knowledge associated with firm growth even more interesting, especially for the non-clustered small firms and the role of imitation spill-overs.

Figure 4 shows a diagram of correlation between imitation and firm growth in clustered and non-clustered regions. As a whole, the correlation between imitation and small firm growth in non-clustered region was found to be highly significant; however, it was not significant for clustered small firms.

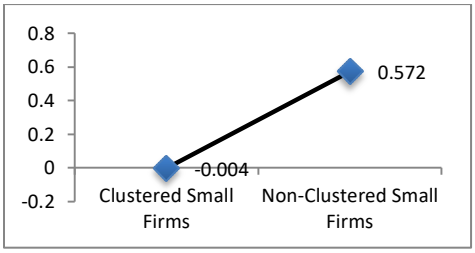


Figure 3: Correlation between Imitation Spill-overs and Growth Performance of Small Firms in Clustered and Non-Clustered Regions

3. Results

3.1 Technology Imitation Spill-overs and Growth Performance of Technology-based Small Firms in Non-clustered Regions

This study hypothesized that technology imitation plays a significant role in the growth performance of technology-based small firms in non-clustered environments. Based on equation (2), the following regression was estimated using OLS that focuses on the impact of a specific knowledge spill-over mechanism, i.e. imitation of non-local firms through reverse engineering on small firm growth, controlling for effects of firm size and age:

$$GROWTH_{i,t} = B_0 + B_1(Size_{i,t-1}) + B_2(Size_{i,t-1})^2 + B_3(Age_{i,t-1}) + B_4(Imitation\ of\ Non\text{-}Local\ Firms_{r,t-1}) + \varepsilon_{i,t} \quad (3)$$

Secondly, the impact of all the knowledge spill-over factors identified was examined together using the formula:

$$GROWTH_{i,t} = B_0 + B_1(Size_{i,t-1}) + B_2(Size_{i,t-1})^2 + B_3(AGE_{i,t-1}) + B_4(University/Public\ Institute_{r,t-1}) + B_5(Conferences/Associations_{r,t-1}) + B_6(Personal\ Contacts_{,t-1}) + B_7(Labor\ Mobility_{r,t-1}) + B_8(Imitation\ of\ Non\text{-}Local\ Firms_{r,t-1}) + B_9(International\ Spill\text{-}overs_{r,t-1}) + \varepsilon_{i,t,} \quad (4)$$

Third, the impact of the knowledge spill-over factors was tested to control the effect of market-mediated knowledge transfer which is measured by technology licensing[2] (Kim, 1999; Breschi & Lissoni, 2001b). This was deemed necessary since technology licensing has also been hypothesized to have an effect on firms (Kim, 1999; Breschi & Lissoni, 2001b). The following formula was used:

$$GROWTH_{i,t} = B_0 + B_1(Size_{i,t-1}) + B_2(Size_{i,t-1})^2 + B_3(Age_{i,t-1}) + B_4(University/Public\ Institute_{r,t-1}) + B_5(Conferences/Associations_{r,t-1}) + B_6(Personal\ Contacts_{,t-1}) + B_7(Labor\ Mobility_{r,t-1}) + B_8(Imitation\ of\ Non\text{-}Local\ Firms_{r,t-1}) + B_9(International\ Spill\text{-}overs_{r,t-1}) + B_{10}(Technology\ Licensing_{r,t-1}) + \varepsilon_{i,t,} \quad (5)$$

Results for the computations are shown in Table 3. In terms of the influence of firm-specific variables (*Size* and *Age*), the estimation of the models yielded standard results especially for *Age* (see models 1, 2 and 3). In general, the negative coefficients for firm age in the equations (see models 1, 2 and 3) are in line with the so-called "stylized finding" that firm growth often declines as the firm evolves over its life cycle (Audretsch & Lehman, 2005a, b; Audretsch & Dohse, 2007). As for *Size* and *Size*^{2}, the coefficients also show a negative sign as expected but are not significant. The negative sign implies that as firms become larger, growth decreases. Moreover, the lack of significance is possibly due to the non-inclusion of large firms in this study's sample. Most important in the context of this study is the influence of imitation spill-overs on firm growth particularly in non-clustered region. The results also show that there is a positive and highly significant relationship between imitation spill-overs (as substituted by *Imitation Spill-overs*) and firm performance for small firms in non-clustered

[2] A composite technology-licensing index was created through principal component analysis by combining the three technology licensing variables which include: (1) license technology of local firms; (2) license technology of firms in the rest of UK; (3) license technology of firms overseas. The Cronbach Alpha score was 0.73.

regions (see models 1, 2 and 3). The positive effect holds even after controlling for the effects of other knowledge spill-over mechanisms (model 2) and technology licensing (model 3). In contrast, imitation spill-overs in clustered regions do not appear to be significant (p>0.1); rather, for clustered small firms, spill-overs from universities/public research institutes and labor mobility, appear to be the most significant. Both factors are also the most cited in the literature as key spill-over mechanisms for clusters (Saxenian, 1994; Audretsch & Lehman, 2005a, b; Audretsch & Dohse, 2007). In summary, the findings suggest that there are some regional differences in knowledge spill-over factors important for firm growth between clustered and non-clustered firms.

Table 3: Knowledge Spill-overs and Small Firm Growth

	MODEL 1			**MODEL 2**			**MODEL 3**		
	All Firms	**Clustered**	**Non-Clustered**	**All Firms**	**Clustered**	**Non-Clustered**	**All Firms**	**Clustered**	**Non-Clustered**
(Constant)	3.423***	3.135***	2.187**	(3.765)***	(2.198)**	(2.151)**	3.710***	2.131**	1.894*
FIRM SPECIFIC									
Size	.068	.249	-.091	.005	.176	-.069	.017	.153	-.006
	(.620)	(1.664)	(-.584)	(.037)	(1.174)	(-.326)	(.137)	(.971)	(-.027)
Size^2	-.010	-.167	-.016	-.001	-.083	-.016	.001	-.080	-.006
	(-.096)	(-1.116)	(-.113)	(-.010)	(-.575)	(-.117)	(.013)	(-.548)	(-.040)
Age	-.231**	-.406***	-.056	-.306***	-.329**	-.215	-.302**	-.330**	-.188
	(-2.054)	(-2.719)	(-.349)	(-2.607)	(-2.211)	(-.131)	(-2.549)	(-2.188)	(-.989)
KNOWLEDGE SPILLOVER FACTORS									
Imitation of Non-Local Firms	.267**	-.124	.559***	.180	-.137	.440***	.201	-.160	.549***
	(2.428)	(-.821)	(3.855)	(1.594)	(-.888)	(2.797)	(1.603)	(-.983)	(3.004)
University/ Public Institute				.184	.336**	.121	.203*	.330**	.296
				(1.669)	(2.297)	(.735)	(1.683)	(2.230)	(1.328)
Conferences/Associations				-.263**	-.243	-.147	-.250**	-.277	-.127
				(-2.371)	(-1.532)	(-.906)	(-2.154)	(-1.588)	(-.782)
Labor Mobility				.273**	.357**	.212	.276**	.360**	.221
				(2.252)	(2.181)	(1.163)	(2.258)	(2.172)	(1.220)
Personal Contacts				-.053	-.012	-.181	-.037	-.037	-.099
				(-.501)	(-.077)	(-1.237)	(-.324)	(-.226)	(-.614)
International Spill-overs				-.021	.199	-.226	-.005	.179	-.173
				(-.194)	(1.356)	(-.297)	(-.045)	(1.158)	(-.967)
MARKET MEDIATED MECHANISM									
Technology Licensing							-.060	.090	-.323
							(-.395)	(.501)	(-1.154)
R^2	.154	.227	.339	.26	.41	.47	.259	.415	.481
Adj. R^2	.109	.141	.262	0.16	0.24	.29	.152	.220	.295
F	3.406***	2.640**	4.364***	2.702***	2.392**	2.702**	2.418**	2.125**	2.592**

*P≤0.1 (2-tailed); ** P≤0.05 (2-tailed); *** P≤0.01 (2-tailed); t-stats are in parentheses

3.2 Robustness Check I: Split Sample Validation - Contribution of Knowledge Spill-overs to Small Firm Growth in Non-clustered Regions

Split sample validation was used to examine the robustness of the influence of knowledge spill-overs, particularly imitation spill-overs, on small firm growth in non-clustered regions. The sample of non-clustered small firms was randomly divided into two for the split sample validation. The interest in this decomposition was to see whether the imitation spill-overs will consistently have a positive effect on firm growth for the two random split-samples. Table 4 presents the results for split sample validation. Consistent with the earlier findings, a positive effect of

imitation spill-overs on small firm growth was found for both Split=1 and Split=2.

Table 4: Split Sample Validation - Contribution of Knowledge Spill-overs to Small Firm Growth in Non-Clustered Regions

	Full Data Set (Non-Clustered)	**Split=0** (Non-Clustered)	**Split=1** (Non-Clustered)
(Constant)	(2.151)**	(.689)	(2.845)**
Size	-.069 (-.326)	.170 (.564)	-.291 (-1.402)
Size ^{2}	-.016 (-.117)	.008 (.074)	.007 (.046)
Age	-.215 (-.131)	-.131 (-.730)	-.101 (-.430)
Imitation of Non-Local Firms	.440*** (2.797)	.968*** (5.116)	.368* (2.080)
University/ Public Institute	.121 (.735)	-.473** (-2.790)	.471** (2.495)
Conferences/Associations	-.147 (-.906)	-.274* (-2.166)	-.152 (-.571)
Labor Mobility	.212 (1.163)	.015 (.055)	.556*** (3.010)
Personal Contacts	-.181 (-1.237)	-.106 (-.771)	-.419** (-2.164)
International Spill-overs	-.226 (-.297)	-.291 (-1.332)	.205 (.860)
R^2	.47	.948	.728
Adj. R^2	.29	.870	.540
F	2.702**	12.138***	3.864**

*P≤0.1 (2-tailed); ** P≤0.05 (2-tailed); *** P≤0.01 (2-tailed); t-stats are in parentheses

3.3 Robustness Check II: Contribution of Knowledge Spill-overs to Innovative Capacity of Small Firms in Non-clustered Region

Robustness of the results was further tested by examining the explanatory power of knowledge spill-overs on the capacity of small firms to generate technological innovation. The interest here stemmed from the argument presented earlier in this paper that imitation spill-overs should enhance small firm growth in non-clustered regions since they are important in influencing technological innovation (Kim, 1997, 1999, and 2001); thus, it is logical to expect that imitation spill-overs will also have an important influence on small firms' innovative capacity. This claim was tested by using the number of patents applied for by small firms as the proxy for innovation capacity. This was done because patents are commonly used in a number of major innovation studies as indicator of innovativeness (Jaffe, 1989; Jaffe et al., 1993; Breschi & Lissoni, 2006). Although patents may not always represent innovation, studies have shown that there is a positive relationship between patents and innovation (Scherer, 1983; Jaffe, 1989; Griliches, 1990). Table 5 shows the results for the influence of knowledge spill-overs on firms' technological innovation capacity with the number of patents used as proxy. Based on the results, imitation spill-overs appear to be consistently positively significant for innovativeness of small firms in non-clustered regions.

Table 5: Knowledge Spill-over and Small Firm Innovative Capacity (Patents) in Non-clustered Regions

	Model 1	**Model 2**
(Constant)	2.096**	1.891*
Size	-.125 (-.560)	-.077 (-.331)
Size ^{2}	-.052 (-.356)	-.041 (-.279)
Age	-.152 (-.770)	-.155 (-.768)
University/ Public Institute	.218 (1.361)	.383 (1.577)

	Model 1	Model 2
Conferences/Associations	.081 (.491)	.060 (.354)
Labor Mobility	.455** (2.320)	.493** (2.452)
Imitation of Non-Local Firms	.270* (1.705)	.340* (1.918)
Personal Contacts	-.265 (-1.642)	-.200 (-1.123)
International Spill-overs	.091	.114 (.591)
Technology Licensing		-.247 (-.879)
R^2	.368	.388
Adj. R^2	.184	.177
F	2.004*	1.838*

*P≤0.1 (2-tailed); ** P≤0.05 (2-tailed); *** P≤0.01 (2-tailed); t-stats are in parentheses

4. Discussion and Conclusion

Despite a growing literature on knowledge spill-overs and small firm performance in clusters, little attention has been given in investigating knowledge spill-over mechanisms important for small firm performance in non-clustered regions. To extend previous research, this paper utilized survey data on technology-based small firms in clustered and non-clustered areas in East of England. The paper examined the influence of different knowledge spill-over mechanisms on small firm growth in non-clustered regions, while using small firms in clustered regions as a control group.

The findings suggest that while university/public institute spill-overs have a significant impact on small firm growth in clustered regions as reported in previous studies (Audretsch & Lehman, 2005, 2007; Audretsch & Dohse, 2007; Maine et al., 2010), for non-clustered regions, a novel finding is that imitation spill-overs appear to be the key external knowledge mechanism that influences small firm growth. The robustness of the results was examined by using split-sample validation and by exploring the influence of knowledge spill-overs on the capacity of small firms to generate technological innovation. The findings suggest that imitation is a crucial source of learning especially for technology-based small firms in non-clustered regions. This is possibly due to limited internal R&D, as R&D spending is higher in clusters (Jaffe, 1989; Saxenian, 1994; Acs, 2002; Stuart & Sorenson, 2003) often because of higher concentration of financial institutions (Florida & Kenney, 1988). This suggests that early technological learning and growth of small high-tech firms in non-clustered regions even in a developed country like England is influenced by imitation. Interestingly, researchers on technological catch-up in developing countries have also observed that reverse engineering had a significant role in the early technological progress of developing countries such as Korea, Singapore and Taiwan (Mishra, 1997; Kim, 1997, 1999, 2001; Wong, 1999; World Bank, 2000). The results suggest that similar to firms in developing countries, technology-based small firms in non-clustered regions also benefit greatly from imitation.

4.1 Implications for Theory

The study contributes to the growing literature on the impact of knowledge spill-overs on the performance of technology based small firms (Audretsch & Lehman, 2005, 2007; Audretsch & Dohse, 2007; Maine et al., 2010). First, the results confirm a major heterogeneity in knowledge spill-over mechanisms important for small firm growth across regions, with clustered firms focused on university spill-overs and labor mobility, while growth performance of small firms in non-clustered regions appears to be influenced by imitation through reverse engineering. Second, the findings support the theory that imitation spill-overs can im-

prove growth performance of small firms in non-clustered regions..

In general, the findings contribute to the call made by Breschi and Lissoni (2001a, b) on the need to understand the nature of externalities that contribute to firm performance especially those in non-clustered regions. The results suggest that imitation especially through reverse engineering of products from other firms is not only effective in enhancing performance of firms in developing countries (Mishra, 1997; Kim, 1997; Wong, 1999) but also important for small firms in non-clustered regions of a developed country.

4.2 Implications for Policy in Non-clustered Regions

The results of the study can be used as a guide for policy formulation especially for regional governments in non-clustered regions. The findings suggest that although knowledge spill-overs are important for performance of small high-tech firms in their regions, care needs to be taken in choosing the specific knowledge spill-over mechanism that will be utilized to improve small firm performance in non-clustered regions. Different learning models appear to underpin the performance of small firms in the two contrasting regions: clustered small firms follow the "learning by research" model, while small firms in non-clustered region, being more technologically lagging, appear to follow the "learning by imitation" model. More specifically, while knowledge spillover policies of increasing university R&D appear to be appropriate for clustered regions, regional governments in non-clustered regions may consider developing policies that will allow small firms to learn from technologies of other firms though appropriate legal means; this is an approach that has largely been overlooked in developed countries.

4.3 Limitations and Further Research

The study carries a number of limitations and implications for further investigation. First, the findings of this research are limited to small firms in high-tech electronic and computer-related sectors; therefore, caution needs to be exercised in extending the findings to other sectors. Further research may be required to establish the study's generalizability to other sectors. Also, although this study used both firm employment growth and technological innovation capacity (as measured by patents) as measures of performance, future studies can extend this research by exploring other performance measures. Third, the focus of this study has been exclusively on small firms; therefore, it will be of interest to compare the use of external knowledge by large firms, in clustered and non-clustered regions. Fourth, the data for the study was collected during the pre-recession period when the UK economy was relatively stable. Soon after the data was collected, the UK economy went into the Great recession, which led to massive job losses and economic uncertainties. The results of this study are more applicable in periods of economic stability rather than recession.

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Appendix A: Knowledge Spill-over Factors Derived from Factor Analysis

	FACTOR 1 University/Public Institute spillovers	FACTOR 2 Spillovers from conferences/Associations	FACTOR 3 Personal Contacts	FACTOR 4 Labor mobility	FACTOR 5 Imitation of Non-Local Firms through Reverse Engineering	FACTOR 6 International Spillovers
LOCAL SPILLOVERS						
'Free' information from Local Universities/Colleges	.514		.650			
'Free' information from Government research organizations	.620					
Reverse Engineering Products of Local Firms	.541					
'Free' Conversations with employees of Local Firms			.650			
'Free' Conversations with Employees of Local Universities/Colleges			.662			
Recruiting new staff from your Local Area (Without compensating previous employer)				.856		
Local Trade associations		.801				
Local Publications or Professional conferences		.747				
Patent Disclosures relating to Local firms	.665					
NATIONAL SPILLOVERS						
'Free' information from Universities/Colleges within rest of UK	.599		.636			
'Free' information from Gov. research organizations within rest of UK	.729					
Reverse Engineering Products of Firms within rest of UK					.898	
'Free' Conversations with Employees of Firms within rest of UK			.540			
'Free' Conversations with Employees of Universities/Colleges within rest of UK	.601		.562			
Recruiting new staff within rest of UK (Without compensating previous employer)				.805		
Trade associations within rest of UK		.766				
Publications or Professional conferences within rest of UK		.598				
Patent Disclosures within rest of UK	.779					
INTERNATIONAL SPILLOVERS						
'Free' information from Universities or Colleges overseas	.621					
'Free' information from Government research organizations overseas	.705					
Reverse Engineering Products of Firms overseas					.852	
'Free' Conversations with Employees of Firms overseas						.740
'Free' Conversations with Employees of Universities or Colleges overseas	.627					
Recruiting new staff overseas (Without compensating previous employer)						.541
Trade associations overseas		.539				.527
Publications or Professional conferences overseas						.544
Patent Disclosures overseas	.704					

Understanding the Effects of Social Buttons in a Learning Game

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Abstract

Game-based Learning is an emerging field of practice that focuses on the use of digital gaming platforms (e.g. learning games) and technologies for purposes of education. This study aims to understand the effect of the addition of social buttons to a learning game platform. The experiment was conducted in a university located in the Northern part of Taiwan. A total of 98 students (51 from the experimental group and 47 from the control group) completed the five-week experiment who were mostly third year students in the university's Department of Information and Management. For the duration of the study, the game platform was programmed to automatically record the activities of the students who are logged on, including those in which they took part in, and to whom they interacted with. In general, this research finding indicates that the addition of a social button to a learning game has indeed a positive effect, and that those students who played in the learning game with a social button improved their quality but not their quantity of learning engagement. Findings of this study suggest that although social buttons do not increase a learner's level of satisfaction, they can improve learning outcomes, and increase the learner's willingness for continued participation.

Keywords: Serious game, learning game, social buttons, learning outcome

1. Introduction

In an effort to create a positive experience in learning, teachers have utilized a wide range of initiatives and practices designed to improve the learning process for students. One such practice is "Serious Game" which integrates games into the learning environment for the purpose of improving students' learning. Game-based Learning is an emerging practice that uses digital gaming platforms and technologies for educational purposes. An increasing number of researches have contributed to the improvement of digital game-based learning (Hwang & Wu, 2012). Most of these researches were focused on the design, implementation, and evaluation of serious games. It is often assumed that fun game play experiences are largely the reason for students' increased interest in studying which results in a deeper and more sustained learning.

Nowadays, different types of social buttons have diffused across blogs, news websites, social media platforms and other types of websites. The term "social buttons" include the various buttons present on web pages, including social bookmarking buttons, voting buttons, sharing buttons and like buttons et al. These buttons allow users to easily express their support to the content of the platform and enable them to recommend it to other users. According to Facebook (Facebook, 2010), social buttons are a major incentive to user behavior on the Internet. For instance, the "Like" and "Share" buttons are highly valuable because they increase the social experience of web users. By increasing the quality and quantity of social bond over the internet, these "likes", "shares" and "tweets" may be

viewed from a new media studies perspective as new types of hyperlinks. Moreover, from an economic sociology perspective, these may open up questions about the increasing interrelation among social experience, technicity and online value (Gerlitz & Helmond, 2011; 2013).

In general, learning is seen as an individual pursuit, however, it is still essentially a group activity. In some specific situations, it is only through "Group Learning" that the most effective mental activity can be achieved. Consequently, "Social Bond" has obvious effects on our willingness to learn and on learning outcomes (Keverne et al., 1997). In addition, it can be expected that the addition of a social button to a learning game may increase the quality and quantity of social bond while engaging in a learning game. It is also expected that certain impacts should occurred during the learning process. The question of how "Like" buttons affect a student's study habits within a "gamified" environment is worthy of further investigation.

The addition of a social button function on the design of the gaming platform appears to be an almost insignificant change, yet, it is clear that such a small feature can positively alter the study habits of a student. This study used "The LEGO Game", a learning game developed on Facebook, to design an experiment comprising 106 university students. These students participated in a learning game wherein "like" buttons were added to the experimental group's gaming platform but not for the control group. After examining the differences in the learning processes of the experimental group and control group, we discuss the effects of the addition of social buttons to serious games on students' learning. Furthermore, we hope that with the abundant behavioral data collected on the gaming platform during the experiment, we will be able to engage in a deeper exploration of the effects of social buttons on students' engagement and learning outcomes.

This study proposes two research objectives:

1. Understand the effects of the addition of social buttons on students' engagement, learning outcome, and willingness to continue participating.
2. Explore the changes of learning behavior on the addition of social buttons in the context of learning games.

2. Literature Review

2.1 Learning Games

Games are activities in which a player must learn a new skill, use it and combine it with other learned skills to overcome challenges, and gain rewards when the game objectives are successfully met (Passos, Medeiros, Neto, & Clua, 2011). This process is competitive and challenging in nature, and provides participants with a certain level of satisfaction, as well as feedback after game completion. In addition, games are interactive, and the varying decisions and behaviors of different participants, can produce different outcomes and responses (Costikyan, 2002). "Gamification" refers to the introduction of game elements to non-game environments in order to improve participants' level of engagement and quality of experience (Deterding et al., 2011). Gamification has been wildly used to encourage people to participate in an activity, increase the effects of the activity, and to help achieve its goals (Luminea, 2013). According to Corti (2006), serious games involve using the influence of computer games to draw end-users' attention and engage them to perform a specific purpose, mainly to develop new knowledge and skills. Serious games are usually employed in education and learning. Gamification and serious games can indeed alter persons' attitudes towards their obligations, be it work or studying. Furthermore, key concepts of games such as goals, rules, challenges, and interaction are also present in several real-world activities; for instance, the learning process. Therefore many previous studies (e.g. Prensky, 2005; Hwang & Wu,

2012; Luminea, 2013) have supported the idea that the use of games can be an effective way of helping people to accept reality, face challenges, and even to perceive themselves as heroes capable of solving their current difficulties and achieving their goals (McGonigal, 2011).

2.2 Social Buttons and the "Like" Button

The goal of introducing social buttons in social platforms is to increase users' interaction with their social group, making them more integrated and inseparable. For example, visual representation of a social button resembles an icon along with an optional counter that shows the number of times a particular piece of content has been liked or shared in a specific social networking site. Each social button is highly specific and is strategically displayed to ensure that the user can easily identify it and read the counter correctly. Very little work has been done in studying and analyzing social buttons. Gerlitz and Helmond (2011; 2013) emphasized the notion of the "like" economy, as a framework to better understand social buttons. According to Gerlitz and Helmond, social buttons provide the simplest way of expressing social bonds between people. By clicking "like," one conveys approval to another person. This type of feature can strengthen individuals' recognition of their social groups, and allows individuals to easily feel acknowledged by groups; therefore, social buttons may create a positive change in the individual's online and real-life behavior. Social influence induces a sense of belongingness and it affects learning behavior in such a way that when a student joins an online study group, it promotes active engagement while studying with the group. Social Influence is a key factor when designing academic courses in higher education. It refers to learning activities that promote students to collaborate work together, usually in a small group, to attain mutual goals. The ever increasing popularity of social media makes it a promising source for the personalization of gameplay experiences. The researcher of this study believes that by involving friends in the social media and present their influence through the social buttons in a learning game, the satisfaction of students can be greatly enriched and their performance during the learning process may be increased.

This study will therefore address the following research questions:

- Do social buttons influence students' engagement in learning game?
- Do social buttons influence students' learning outcomes in the learning game?
- Do social buttons influence students' willingness to continue participating in the learning game?

3. Research Method

3.1 The LEGO Game: Game Platform and the Learning Game

Academic courses in the university usually require students to read extensively before commencing with the course; generally, students tend to skim through the course material without actually reading it in detail. "The LEGO Game" is a game platform on Facebook that uses gamification to motivate students to complete this mandatory reading.

In "The LEGO Game", teachers create a list of requisite readings and a timeline is set for its completion. Students can log on to the platform to read before the deadline. After completing the required readings, the student has the option to write questions, with reference to the reading, for their classmates to answer or they can answer the questions provided to test their memory and comprehension.

Figure1: The LEGO Game

Both creating questions and answering questions can earn points for students, which can then be used at the LEGO store to buy LEGO bricks. At the end of the semester, students can utilize their bricks to compete in a LEGO building competition.

Students are also allowed to challenge their classmates to compete in answering questions to make the game more interesting; subsequently, the winner can claim the points of the loser. Apart from LEGO bricks, the LEGO store also sells "magic cards" which can be used during games(for example, the bomb card can be used to blow up all the LEGO bricks that belong to an opponent; while a defense card can protect a player from the opponent's bombs).

Figure2: The LEGO Store and the LEGO Building Competition.

3.2 Experimental Design

The experiment was conducted in a university located in the Northern part of Taiwan. A total of 124 senior undergraduates enrolled from the "Software Project Management" course were chosen for the study. Students were provided with five pre-reading materials related to project management that need to be completed within five weeks. They were equally divided and randomly assigned into two groups: experimental group and control group. Those in the experimental group were asked to use a gaming platform with social buttons, while those in the control group were also provided with the same gaming platform but without the social buttons. A total of 106 students agreed to participate in the experiment (55 for the experimental group and 51 for the control group), mostly third year students in the university's Department of Information Management. Member of the experimental group were asked to answer a set of questions. Each question was accompanied by a "like" button, with a "like" counter displayed beside it. Those who approved of the question were asked to press the "like" button. The number of "likes" the question has gained could then be seen on the personal page of the author.

The five-week experiment was successfully completed by 98 students: 51 from the experimental group and 47 from the control group. There were no significant differences in the gender and age demographics among the experimental and control group. During the study, students had generated 4,296 questions and which were answered 20,600 times. On average, each student spent 30.40 hours playing the game. To help researchers analyze the status of the students throughout the five week period, , the platform was programmed to automatically record the activities of the students, including those in which they took part in, as well as to whom they interacted with every time they log on to The Lego Game.

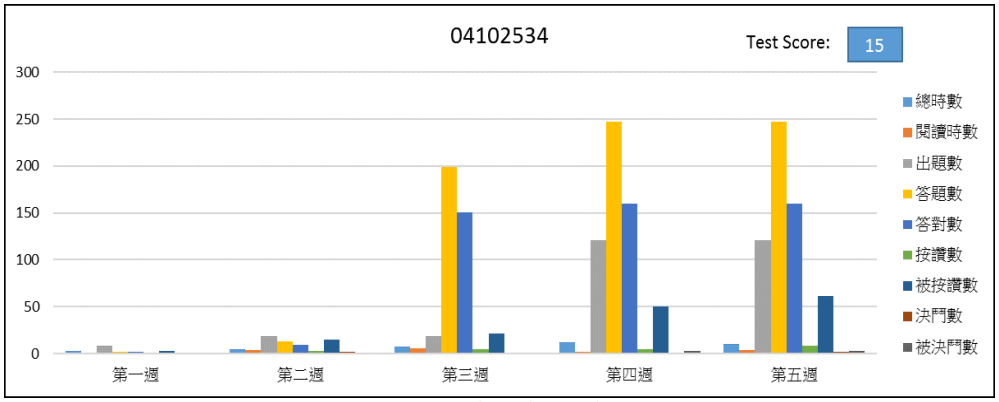

Figure3: The Study Profile of a Student "04102534"

Students' engagement was measured by: (1) the amount of time spent in the game platform, (2) the number of question that the student generated, as well as (3) the number of questions answered.

The quality of students' engagement on learning was measured by assessing the quality of questions generated by both the experimental and control groups. This was done by randomly selecting 100 questions from all the questions generated by the students each week (50 questions from each group). Questions from different groups are then mixed and assessed by three teaching assistants (All were graduate students in the IM Department). In order to ensure inter-rater reliability, only the questions that had receive consistent rating from all three TAs were accepted (the rating scale used was 0-10 point with 0 being the lowest and 100 being the highest; the difference among the ratings from three TAs cannot exceed 1.0). The result of the assessment on the quality of the questions was then used to determine if there was a difference in the quality between the experimental group and the control group.

Subjective measurement for students' learning outcomes was done by asking the students to assess their own feelings of satisfaction with regard to their learning outcome during the experimental period. The score of their final test serves as an objective measure of the learning outcomes. Students' willingness to continued participation was measured through administration of a willingness evaluation questionnaire,

Participants were required to undergo a 50-item final test, scored by the instructor, at the end of the experiment to determine their learning outcome. To ensure the validity and objectivity of the test, all questions were multiple choices with clear correct answers. These questions were derived from the reading material that the students had been given at the start of the experiment. After this, students were required to complete a questionnaire to evaluate their satisfaction with their learning, and their willingness to continue participating in the learning game.

4. Research Analysis

A comparison of each group's engagement, learning outcome, and willingness to continue participating were done. Subsequently, the differences in each group's learning process due to the presence or absence of social buttons were also explored.

1. Do social buttons influence students' engagement?

It is interesting to note that there was no significant difference between the groups, in terms of (1) the time spent on the gaming platform (Table 1, p=.385), (2) the number of questions generated (Table 2, p=.229), and (3) the number of questions answered (Table 3, p=.52). Further analysis

revealed that during the first two weeks of the experiment, the experimental group surpassed the control group for these metrics; but during the next 3 weeks, the control group began to catch up with the experimental group, and eventually outdid them. Researchers believe that the two primary factors that allowed the participants to continue and finish the serious game are: first, there is the positive incentive of it being an interesting game; and second, there are negative consequences for not completing the required work such as penalties. Towards the end of the experiment, when there was limited time to complete the game, students who were not previously involved, responded to this negative incentive by working harder to make up for lost time.

Table 1: The Time Spent on the Gaming Platform

	Group	Number	Means	Standard Deviation	Standard Error	t-value	Degree of Freedom	p-value
Time on Gaming Platform	With Button	51	6.43	4.415	0.618	0.872	96	0.385
	Without Button	47	5.70	3.805	0.555			

Table 2: The Number of Questions Generated by Students

	Group	Number	Means	Standard Deviation	Standard Error	t-value	Degree of Freedom	p-value
No. of Questions Written	With Button	51	52.82	84.75	11.865	1.21	96	0.229
	Without Button	47	34.09	66.676	9.726			

Table 3: The number of questions answered

	Group	Number	Means	Standard Deviation	Standard Error	t-value	Degree of Freedom	p-value
No. of Questions Answered	With Button	51	194	304.1	42.58	-0.645	96	0.52
	Without Button	47	227.8	197.9	28.87			

Nevertheless, as debated in the fields of management, positive incentives encourage people to do something well, but negative incentives encourage people to work merely to incur the minimal damage. This was reflected in the TAs' assessment of the quality of questions generated by the student themselves, where the quality of questions written by students in the experimental group was evidently better (Table 4, p=.062) and more consistent. Comparatively, although there was a small difference in the number of questions written by the control group (Table 2, p=.229), their overall quality was significantly lower with a wide disparity between the good and bad questions. Moreover, the control group preferred to answer questions written by others rather than to write the questions themselves since it was the more efficient way of accruing points. Members of the experimental group wrote an average of 52.82 questions while the control group wrote an average of 34.09 questions only (Table 2). Consequently, members of the control group responded to 227.8 questions on an average while the experimental group responded to only 194 questions (Table 3).

The analysis results suggest that social buttons did not affect the quantity measures of students' engagement; however, it seems that social buttons did have a significant

influence on the quality of student's engagement on the game.

Table 4: The Quality of Questions Written by Students

	Group	Number	Means	Standard Deviation	Standard Error	t-value	Degree of Freedom	p-value
Quality of Questions Written	With Button	51	3.31	8.32	1.165	-1.887	96	0.062
	Without Button	47	14.47	41.336	6.03			

2. Do social buttons influence students' learning outcomes?

It is noteworthy that the addition of social buttons did not have a significant effect on students' self-assessment of learning outcome satisfaction (Table 5, P=.302), but comparison of each group's performance on the final test revealed a clear difference. Out of 20 questions, the experimental group, answered an average of 13.88 questions correctly; whereas the control group, answered an average of 11.26 questions correctly (Table 6, P=0.001).

The researchers believe that the stimulation the serious game provided was the main factor responsible for a student's increased satisfaction with the learning outcome. Even though the difference between the scores of the experimental group and control group are small, the former having scored 4.6 compared to the latter's 4.43, both of these scores are still relatively high when compared to the more traditional pre-course reading activity, having a satisfaction level below 4.00. Therefore, it is evident that the serious game has a perceivable effect on students; however, research data indicates that students do not necessarily realize the social influence that accompanies the use of social buttons, or its positive effect on their studies.

Table 5: The Students' Self-Assessment of Learning Outcome Satisfaction

	Group	Number	Means	Standard Deviation	Standard Error	t-value	Degree of Freedom	p-value
Satisfaction of Learning Outcomes	With Button	51	4.60	0.629	0.088	1.039	96	0.302
	Without Button	47	4.43	0.935	0.136			

Table 6: The Students' Performance on the Final Test

	Group	Number	Means	Standard Deviation	Standard Error	t-value	Degree of Freedom	p-value
Learning Outcomes	With Button	51	13.88	4.107	0.575	3.368	96	0.001
	Without Button	47	11.26	3.566	0.52			

On further examining the data generated by the study, the researchers discovered that the effectiveness of social buttons on learning outcomes varied from that predicted by the general theory of motivation. Moreover, there was no significant difference in the learning outcomes (Table 7, P=.551) between the eleven students from the experimental group who received frequent "likes" (received at least one "Like" each week) and the other 40 students. Obviously, there is no evidence to suggest that when a student receives "like" more frequently, it will result in a better study habit.

Comparatively, the 18 students who pressed "liked" on others more frequently (click at least one "Like" in each week), compared to the other 33 students, clearly

had better learning outcomes. They scored an average of 16.33 out of 20 in the final test, compared to those students who did not pressed "like" frequently (P=0.001) who only scored 12.55. Clearly, those who pressed "like" frequently had a higher level of engagement and scored higher marks in general. The number of questions they had answered and the number of question they had written were both significantly higher than others as well (P=0.026 and P=0.001).

3. Do social buttons influence students' willingness to continue participating?

As described above, the presence of a social button on a gaming platform does not necessarily result in higher levels of satisfaction on the students' learning outcome. Consequently, it is not expected that a significant difference between the two groups' willingness to continue participating in a similar serious game setting will be apparent. According to the results of this study, however, the experimental group was evidently more willing to participate in a similar study in the future as compared to the control group (Table 9, P=0.071). The researchers believe that this finding is consistent with Gerlitz & Helmond's (2011; 2013) observation that social buttons can foster an individual's integration into a social group. Social buttons may not have the effect of increasing an individual's satisfaction, but it can make an individual more likely to continue using the social platform.

Table 7: Difference of the Learning Outcome between Students Who Received "Likes" Frequently and Others

	Group	Number	Means	Standard Deviation	Standard Error	t-value	Degree of Freedom	p-value
Learning Outcomes	Received "Like" Frequently	51	14.55	5.592	1.686	0.601	49	0.551
	Others	47	13.70	3.667	0.580			

Table 8: Difference of the Learning Outcome between Students Who Click "Likes" Frequently and Others

	Group	Number	Means	Standard Deviation	Standard Error	t-value	Degree of Freedom	p-value
Learning Outcomes	Clicked "Like" Frequently	51	16.33	4.116	0.97	3.48	49	0.001
	Others	47	12.55	3.483	0.606			

Table 9: The Students' Willingness to Continue Participating

	Group	Number	Means	Standard Deviation	Standard Error	t-value	Degree of Freedom	p-value
Willingness to Continue Participating	With Button	51	4.61	0.645	0.090	1.828	96	0.071
	Without Button	47	4.24	1.266	0.185			

5. Research Findings and Discussion

1. Social buttons help students to focus on the quality of their learning instead of game play.

Our research finding has shown that social buttons do not prompt students to spend more time playing learning games, or to complete additional homework. Instead, with the addition of social buttons, students are more likely to pay attention to the quality of their work (the questions they had written). This study also found that students in the experimental group had performed better during the final test than those in the control group. The authors of the study believe that the reason for this is that the social buttons make students real-

ize that their actions will be evaluated by their classmates, and that their classmates' perception of the quality of their work will be evident in the number of "likes" it receives. This potential of social influence can make students voluntarily pay more attention to their work. Comparatively, the students in the control group, though will still play the game with the same enthusiasm and for approximately the same amount of time, but they are more likely to spend time on the more rewarding and less effort-consuming portions of the game (e.g. answering questions instead of writing questions). They will not be as willing to exert themselves in writing questions, despite the fact that this is more important from the learner's point of view.

2. In a vivid serious game, the effects of social influence may be hidden and may not be sufficiently perceived by the students.

Our research has clearly shown that the addition of social buttons has helped increase the learning outcomes of students; however, it is more likely that the excitement brought about by the serious game itself had resulted in the students increased level of satisfaction and not the social button. Accordingly, the association between the addition of social buttons and students' level of satisfaction is unclear (P=.302) even though this study found that students in the experimental group have greater levels of test performance than those in the control group. It is apparent that the students had perceived the effect of the serious game; however, they have not observed the social influence or the positive effect of social buttons on learning outcomes as easily.

3. The affirmation through social buttons does not necessarily encourage students to intensify their engagement or improve learning outcomes.

Our research has shown that there is no evidence that when students get "like" more frequently, they will study harder and have a better score on the final test. Alternatively, those students who pressed the "like" button for others more frequently are actually more involved and obtained better outcomes. The act of "liking" another student's post is mostly only a sign of approval or an indication of social interaction, and is not an effective motivator for those who have received them.

4. The social bond created by social buttons can increase willingness to continue participating.

Our finding has clearly shown that the experimental group with social buttons was more willing to participate in similar future learning activities than the control group. The researchers believe that this finding indicates that social buttons can improve an individual's engagement within a social group. Social buttons do not cause an individual to be more satisfied with their learning outcome, but can generate a type of social bond that makes a student want to continue participating in these types of learning activities.

6. Conclusion and Limitations

The use of serious games and gamification can help improve students' learning engagement and outcomes. The LEGO Game platform utilized in this study came in use in 2012 and since then, has seen to clearly improve the engagement of students towards pre-course required reading. Simply put, as time spent studying increases, satisfaction and educational outcomes also improve; also, students are more willing to participate in similar activities in the future. This study was focused on the effect of the addition of social buttons to The LEGO Game platform. In general, our research finding indicates that there is indeed a positive effect with the addition of social buttons, and that students who used The LEGO Game with social buttons improved

their quality of engagement, learning outcomes, and increased their willingness to continue participating.

The findings of this study had mainly explored the effects of social buttons, and had identified important trends for further deliberation. This study was exploratory in nature; therefore, its observations will likely require further research to establish their validity. It is possible that the mechanism through which social buttons increase student's test performance are different from the mechanisms through which social buttons affect involvement and outcome satisfaction. The researchers believe that it might be related to how the social button increases the individual's visibility within the social group, however, further study might be needed for this.

Research of this type is rare, and the authors of this study believe that its findings are valuable for teachers and researchers who are interested in contemplating the effects of integration of learning game and social buttons.

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