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Contents

From the Editor

The Volume 8 Issue 2 brings together a collection of five edited papers which explore modern concepts of management theory and practice. The papers, whose authors represent scientific institutions from Europe, Asia, and the U.S., consider a variety of complex issues, namely affective management, scheduling algorithms, patent rights, the role of the Internet in managing business organizations, and strategic decision making with real option valuation models.

In the first paper, Waratta Authayarat and Hiroyuki Umemuro use the data on Thai firms to examine how practicing affective management can affect the organizational performance. The second paper by Chia-Shin Chung, James Flynn, Walter Rom and Piotr Staliński examines the performance of various numerical approaches to solving a complex scheduling problem of determining the optimal sequence of tasks in a multi-machine factory setting. Haim Levy discusses the economic and practical issues of the transferability and commercialization of patent rights in the third paper. Neema Mori and Gibson Munisi, the authors of the fourth paper, investigate how the Internet can help overcome the export barriers faced by small and medium-sized enterprises operating in East African countries. In the final paper of this volume, Gordon Sollars and Sorin Tuluca discuss a real option valuation model that can guide the first mover strategic decision making.

We believe that the papers in this volume will contribute to a better understanding of the complex decision making processes in managing business organizations in the wide international context and will provide stimuli for further research.

We would like to express our gratitude to the authors for their contributions to this volume. We are grateful to the reviewers for providing the meaningful feedback. We would also like to thank all those who provided us with their valuable comments and supported us in the process of editing this volume. We hope that you will enjoy reading it.

Piotr Staliński
Co-Editor in Management, JEMI

Affective Management and its Effects on Management Performance

Waratta Authayarat[*]*, Hiroyuki Umemuro*[**]

Abstract

Affective management is a new concept which suggests that top managers should take stakeholders' affective experiences into account when making their management decisions. To show that this concept could contribute to the improvement of management performance in organizations, this study investigated the correlations between the affectiveness of top management and management performance indices. Our questionnaire based on the Affective Management Scorecard was employed to assess top managers' recognition of the importance, as well as the actual practices of affective management. Top managers from 43 Thai organizations participated in the study. A correlation analysis was conducted to observe whether affective management indices would correlate with management performance indices, such as return on equity, return on assets, price to earnings ratio, and price to book value ratio. The findings showed that the results for organizations practicing affective management were positively correlated with their management performance in both profitability and good perceptions by investors.

Keywords: affective management, stakeholder, management, affect, emotion, feeling.

Introduction

In principle and in practice, management decision-making has traditionally been based on objective measurements such as costs, sales, benefits, and efficiency. Recently, a new concept emerged suggesting that those objective measurements might not be a sufficient basis for decision-making, and that decisions focusing on the affective experiences of all stakeholders, as well as the objective measurements, would be more appropriate (Authayarat, Umemuro, Murata, and Jiamsanguanwong, 2011; Strong, Ringer, and Taylor, 2001; Umemuro, 2009, 2011). *Affective management* is defined

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as management that takes stakeholders' affective experiences into consideration in management decisions (Umemuro, 2011). The capability of top management to consider the affective influence on stakeholders (hereafter *affectiveness*) is an important measure to evaluate management quality or overall organizational quality (Umemuro, 2011).

Conventional management has emphasized efficiency, including reducing costs, but affective management emphasizes the stakeholder's affective experiences. For example, a product might be designed especially for a customer, deliberately including superior building design, quality materials, and skilled finishes, and this may result in additional costs (Umemuro, 2009). Thus, when top management considers affective experiences of stakeholders, the idea may conflict with conventional management theories based on rational and objective measurements (Authayarat et al., 2011; Umemuro, 2009). To claim that affective management actually leads to better performance, the relationship between the extent to which management considers stakeholders' affective experiences in their decisions and actual organizational performance needs to be established.

To show the effectiveness of affective management, it is crucial to have the means to measure it. Two approaches for evaluating affectiveness are possible. One is to perform an evaluation based on publically available information, such as financial reports or corporate social responsibility (CSR) reports. However, as public information is authored by the organizations themselves, the information may be biased. Another way is to base the evaluation on the direct assessment of top management, through such means as interviews or questionnaires. Although this approach may be costly, the results would be highly accurate and trustworthy if systematic measurement methods were employed. Authayarat et al. (2011) proposed the Affective Management Scorecard to assess and quantify the affectiveness of an organization. This study employed this scorecard as a measurement of affectiveness of organizations, and compared the results with conventional management performance.

The purpose of this study was to investigate the relationship between the affectiveness of organizations' top management and their management performances. A questionnaire-based investigation was conducted with top management from 43 Thai organizations. The Affective Management Scorecard was employed to assess the affectiveness of the respondents. Overall scores of affectiveness were calculated and an analysis performed by stakeholder categories. These scores were compared with management performance indices for profitability and market valuations.

Related works and hypotheses

Affective management

In psychology, the term *affect* has long been used to represent a person's general response, including emotion, mood, and feeling. In this study, *affective* is defined as

being capable of involving a person's mind or as being capable of provoking deliberate responses in a person's mind (Umemuro, 2009).

Affective management can be defined as "management of an organization that takes into consideration the potential influences of its decision-making on its stakeholders' affects or affective experiences" (Umemuro, 2011, p. 514). Affective management should recognize what might potentially influence people's affects and evaluate the possible impacts. This concept promotes the idea that top management should make decisions considering not only conventional quantitative indices but also the effects of decisions upon the affective experiences of stakeholders (Authayarat et al., 2011; Umemuro, 2009, 2011).

Although the concept of affective management may have only recently emerged in the field of management, successful managers have long understood the influence of affect in their decisions and behaviors. However, those managers have practiced this concept implicitly or subconsciously, as it has not been explicitly identified and still remains in the shadows of rational decision-making (Umemuro, 2009). Amsa (1991) reports the urgent need for "a mature ideational construct and conceptual framework for understanding and improving the affective world of management students or the embryo managers" (p. M130). This desire is to prepare tomorrow's managers to relate to the real world—to its emotions, passions, dispositions, motives, moral and aesthetic sensibilities, capacity for feeling, concern, attachment or detachment, sympathy, and appreciation (Amsa, 1991). To further understand, endorse, and promote this concept, we need evidence that it also promotes good management performance.

Stakeholders of affective management

A stakeholder is defined as any individual or group who affects or is affected by the organization and its processes, activities, and functioning (Carroll and Näsi, 1997). Frequently, companies only focus on the specific stakeholder targets stated in their company mission statement or annual report (Campbell, Shrives and Bohmbach-Saager, 2001). However, the affective management concept requires that not only customers, but also employees, the local community, and society in general should be included. Top management should pay attention to the affects of these stakeholders.

Customers as stakeholders

Management is concerned with many aspects of how the company can best serve its customers (Bahn, Lee, Nam, and Yun, 2009; Larson, 2009; Locke 1996; Millard, 2006; Parasuraman, Zeihaml, and Berry, 1988). It is common for consumer-oriented product development to be the focus because there is competition between goods in the market. Customers tend to buy attractive products or services that affect their feelings (Nagamachi, 2008). Tang and Umemuro (2012) extracted the affective factors that can elicit a person's emotions in products. Vendors of products and services should not only be concerned with the functionality and usability of the products, but should

also find out how their products can evoke customers' emotions such as feelings of enjoyment or pride (Norman, 2004).

The customer's affective experience, through word-of-mouth, ownership, and by providing suggestions and complaints, is the first stage in developing loyalty and commitment (Millard, 2006). Once customers perceive high quality service or have positive affective experiences with products or services, they become loyal customers (Devaraj, Matta, and Conlon, 2001; Lewis and Soureli, 2006). Retaining loyal customers who positively and intentionally spread recommendations by word-of-mouth makes good business sense (Millard, 2006) and is sustainable over a long period (Locke, 1996; Reinartz and Kumar, 2003). Significantly, perceived service quality improves the company's sales performance (Babakus, Bienstock, and Scotter, 2004). From the investors' perspective, Nayyar (1995) reported that improvements in customer service are positively valued and decreases in customer service are negatively valued by the stock market.

The nature of businesses can vary depending on the target customers, being either personal customers or business customers. Business-to-customer (B2C) and business-to-business (B2B) companies are different. B2C companies may focus more on the importance of customers' affective experiences to increase their share and survive in the market with the general public, while B2B companies rely on more specific and a limited number of business customers. Thus, the concern from top management toward customers or business customers may be unequal. This idea leads to the first and second hypotheses.

H1: Management that takes care of and considers the importance of customers' affects tends to have higher management performance.

H2. The correlations between affectiveness and management performance of B2C are higher than for B2B.

Employees as stakeholders

Employees are one of the most important mechanisms that drive and maintain an organization. The consequences of employees' positive affective experiences have received much attention and have been widely acknowledged (Fisher, 2003; Lyubomirsky, King, and Diener, 2005; Staw and Barsad, 1993; Zelenski, Murphy, and Jenkins, 2008; see Fisher, 2010 for review). The claim by Zelenski et al. (2008) that employees' positive affects contribute to productivity is similar to other studies (Fisher, 2003; Lyubomirsky et al., 2005; Staw and Barsade, 1993). Previous studies have suggested that employees who experience more positive affects are more productive, and thus people are at their most productive when experiencing positive moods (Harter, Schmidt, and Hayes, 2002).

Positive affects among employees also increase task persistence and performance, resulting in higher motivation levels (Erez and Isen, 2002; Ilies and Judge, 2002; George and Brief, 1996). Positive affect is associated with the process of motivating employees (Fisher, 2010, Fredrickson, 2003). Positive affective experience may result in job

satisfaction and employee engagement with the organization, which are also likely to be associated with employee effectiveness and good job performance (Harrison, Newman, and Roth, 2006).

Engagement of employees is also related to their happiness (Stair and Galpin, 2010). Strong engagement improves effort and employee performance (Hodges and Asplund, 2010). Engagement is a concept that goes beyond "satisfaction" or "motivation" (Stairs and Galpin, 2010). It involves positive affective experiences regarding work, and as a result employees are willing to go the extra mile to complete jobs to the best of their abilities (Truss, Edwards, Wisdom, Croll and Burnett, 2006). Earlier studies have shown that organizations with strong employee engagement achieve higher profits (Harter et al., 2002, 2010). Affective involvement of employees as stakeholders leads to the following hypothesis:

H3: Management that takes care of and considers the importance of employees' affects tends to achieve higher management performance.

Local community and society as stakeholders

The local community stakeholder refers to a community nearby to an organization, and one that interacts with the organization; society stakeholder refers to people in the general public (Authayarat et al., 2011). Affective management should also take care of people outside the organization, in terms of both emotional and well-being issues.

Organizations may reinforce the positive affective experiences of the community through various activities. These may include taking good care of the community environment, providing financial support to community activities such as sports or education, and by providing special experiences such as inviting local people to view the production facilities. These generate the community's positive affective experiences towards the organization and increase the engagement of local customers. As a result, they promote community sustainability and, in turn, bring reputational profits to the organization and increase the long-term market valuation (Bird, Hall, and Momentè, 2007).

Providing affective experiences for society members is a significant challenge for affective management. Organizations are considered as social actors embedded in society and responsible for social activities by providing products and services to social members as they are needed (Branco and Rodrigues, 2006). Society is protected by CSR activities that are designed to prevent or repair the negative impact of the business or operations on society (Branco and Rodrigues, 2006), and, on a larger scale, improve quality of life (Holme and Watts, 2000, cited in Branco and Rodrigues, 2006). The benefits from such activities may attract interested people in society who are current or potential customers and, thus, may become a potential trend for sustaining organizational growth (Authayarat et al., 2011) and financial performance (Branco and Rodrigues, 2006; McWilliam and Siegel, 2000). The business benefits of CSR can also include economic sustainability through developing and enhancing relationships

with customers through products or services, increasing customer and shareholder retention, and developing the company's networks. As a result, organizations that apply CSR develop a unique selling point that sets them apart from competitors (Bird et al., 2007; Whitehouse, 2006); for example, by reducing energy costs (Bird et al., 2007). CSR is a way of achieving long-term results and maintaining business continuity (Branco and Rodrigues, 2006).

The size of the organization may influence the practice of affective management. In the case of CSR, small companies tend to be less familiar with the concept and might find it difficult to put it into practice (Broeck, 2009). Affective management might be in a similar situation. Large organizations with many employees may be more concerned with affective management than small ones. The notion of community as stakeholders leads to the fourth, fifth, and sixth hypotheses.

H4: Management that considers and responds to the importance of the local community's affects tends to have higher management performance.

H5: Management that considers and responds to the importance of society's affects tends to have higher management performance.

H6: The size of an organization affects how it recognizes and practices the affective management concept.

Method

Participants

Participants were top managers of organizations listed on the Stock Exchange of Thailand. A questionnaire was sent to 380 businesses in six sectors: service (22.1%), consumer products (10.3%), property and construction (28.7%), agricultural and food (10.5%), resources (7.1%), and industrial products (21.3%).

Procedure

This investigation was conducted between early March and May 2011. Each participant received a questionnaire as well as a brief outline explaining the concept of affective management and the importance of top managers taking part in this research. The questionnaire investigated the extent to which participants recognized the importance of considering stakeholders' affects when making management decisions, and the extent to which they actually put affective management into practice. Participants were asked to provide demographic data and profiles of their organizations. Participants were also asked to complete the questionnaire in their own time and return it to the investigator by post.

Measurement

The Affective Management Scorecard developed by Authayarat et al. (2011) was used to measure affectiveness in this study. This scorecard consists of 15 dimensions, such as a company's products or services, company's brand, and company's philosophy and

corporate identity. These dimensions corresponded to issues that the top managers would have to make decisions about in the course of their jobs (see Table 1 for overall dimensions and relations with each stakeholder). For each dimension, there were three question types. The first type asked whether the respondent made decisions on issues in each of the 15 dimensions (e.g., "Do management boards make decisions about the company's philosophy and corporate identity?"). The second type asked how much the top manager believed that each of the 15 dimensions was important to each of the stakeholders' affects (e.g., "How much do management boards believe that the company's philosophy and corporate identity are important for employee's affects?"). The final question type asked to what extent top managers actually considered stakeholders' affects when they made decisions regarding the 15 dimensions (e.g., "To what extent do management boards consider employee's affects when making decisions about the company's philosophy and corporate identity?"). For the second and third type of questions, participants were asked to respond using a five-point Likert scale (1 = not at all, 5 = very much). In the process of developing a scorecard and improving its reliability, the content was examined by specialists from various fields of industry and tested with pilot samples that were not a target group. Thus, the scorecard was considered to have valid items and high reliability (Cronbach's alpha = 0.96) (Authayarat et al., 2011).

Based on the responses, two types of affectiveness scores were calculated: a winning score and an average score. Table 2 illustrates how the winning score was calculated. Winning score reflects how top managers recognize both the importance of stakeholders' affects (Im or importance score) and actually consider them when making decisions in practice (Pr or practice score). Likert scale responses were coded into levels (scores of 4 or 5 coded as high, 3 as medium, and 1 or 2 as low) of affectiveness for each decision-making dimension and each stakeholder. The winning scores reflected combinations of recognition of importance and actual practice and ranged between –2 and +2. For example, if a respondent scored the "importance" of a question item as "high" (4 or 5) and the actual "practice" of it as "medium" (3), the winning score for the item will be +1. In the same way, if the "importance" was scored as "high" and the "practice" was scored as "low", the score will be 0. Positive winning scores represented top managers who both recognized the importance and actually considered the stakeholders' affects in their decision-making. Conversely, negative scores reflected the managers who neither recognized the importance of stakeholders' affects nor practiced affectiveness. The average of the winning scores across all dimensions and all stakeholders was defined as the *affectiveness winning score.*

Table 1. Affective Management Scorecard dimensions and relations with each stakeholder

No.	Dimension	Stakeholder							
		Customer		Employee		Local community		Society	
		Im	Pr	Im	Pr	Im	Pr	Im	Pr
1	Company's product/service	O	O	O	O	O	O	O	O
2	Company's philosophy and corporate identity	O	O	O	O	O	O	O	O
3	Company's brand	O	O	O	O	O	O	O	O
4	Business strategy or plan, project management, business process, performance of company's activity	O	O	O	O	O	O	O	O
5	Organization's structure	O	O	O	O				
6	Company's investment	O	O	O	O			O	O
7	Price of product or service	O	O			O	O	O	O
8	Human resource			O	O	O	O		
9	Advertisement and customer's community or communication	O	O	O	O	O	O	O	O
10	Product patent and industrial standard (e.g., ISO, JIS)	O	O	O	O			O	O
11	Office equipment			O	O				
12	Atmosphere at workplace and team management			O	O				
13	Payment and welfare system (e.g., job training, education, health care system)			O	O				
14	Location and construction design	O	O	O	O	O	O	O	O
15	CSR activity	O	O	O	O	O	O	O	O

Note. "Im" indicates importance score; "Pr" indicates practice score; "O" indicates that top management was involved in decision-making for that particular dimension and stakeholder.

Table 2. Winning Score System

		Practice		
		High	Medium	Low
Importance	High	+2	+1	0
	Medium	+1	0	–1
	Low	0	–1	–2

The second score type, average score, was a simple average of responses on the Likert scales across all dimensions and stakeholders. For ease of understanding, the average scores were converted linearly as a range of 0–100. Affectiveness average scores represented the overall tendency of how top managers recognized the importance of and actually considered the stakeholders' affects when making decisions. Average scores were also calculated for each stakeholder, calculating averages across 15 dimensions and across recognition and practice, and further

converted to a range of 0–100. These average scores by stakeholders are referred to as stakeholder sub-scores (e.g., customer sub-score, employee sub-score) hereafter.

Return on assets (ROA), return on equity (ROE), price to earnings ratio (PER), price to book-value ratio (PBR), and profit after tax as of the end of the fiscal year 2010 were used as measurements of management performance. These data for the participants' organizations were sourced from the Stock Exchange of Thailand (www.set.or.th/en/index.html), which has had sufficient liquidity and efficiency in previous years, and thus stock prices used in this research can be considered as efficiently or reasonably priced (www.set.or.th/en/market/market_statistics.html#annual). In addition, log values of number of employees as of the end of the fiscal year 2010 were used as an index of the size of the organization.

Results

Of the 380 questionnaires sent to top managers, 43 were completed and returned. Table 3 shows the demographic data of the participants. The majority of respondents were male (79.5%). Most of the participants were aged between 41 and 60 years old and had gained a master's degree.

Table 4 shows the number of participants by industry sector. Overall the return rate was 11.3%, while return rates of the industry types were 7.1% for service, 10.3% for consumer products, 11.0% for property and construction, 12.5% for agriculture and food products, 18.5% for resources, and 13.6% for industrial products. The proportional returns of each industry type were essentially in the same, approximately 10%, thus the respondents can be said to represent samples of all the industries. Of the 43 respondents, 23 were engaged in B2B businesses, 15 in B2C businesses, and 5 were engaged in both B2B and B2C businesses as shown in Table 5.

Correlations between affectiveness and management performance

A series of correlation analyses was conducted to investigate the correlation between the affectiveness scores and management performance of the organizations. Although the number of samples in this study is rather limited, it is still possible to argue the relationships between affectiveness scores and performance indices when significant correlations are available. Thus, correlation analysis was adopted in this study.

Table 6 shows the Pearson's correlation coefficients between affectiveness scores (affectiveness winning scores, average scores, and stakeholders sub-scores), ROA, and ROE. Table 6 shows that there were no significant correlations between overall winning score or average score and financial performances (ROA and ROE). However, employee sub-score was moderately correlated with ROA ($r = 0.30$, $p < 0.10$). This result means that companies with high employee sub-scores tended to have high ROA. Thus, these findings suggest that organizations that care about employees' affect are more likely to yield stronger financial performances.

Table 3. Demographic data of respondents

		Number of responses [a]	Percentage
Gender	Male	31	79.5
	Female	8	20.5
	Total	39	100.0
Age	<40 years old	7	20.0
	41–50 years old	13	33.3
	51–60 years old	14	35.9
	> 60 years old	5	12.8
	Total	39	100.0
Education	Bachelor's degree	11	28.2
	Master's degree	25	64.1
	Doctor's degree	3	7.7
	Total	39	100.0

Note. [a] The total number in each subcategory may not equal 43 because of missing data.

Table 4. Respondent population by industry sector and response rates for questionnaires

Types of industry	Sent (n, (%))	Returned (n, (%))
Service	84 (22.1)	6 (14.0)
Consumer products	39 (10.3)	4 (9.3)
Property and construction	109 (28.7)	12 (27.9)
Agro and food products	40 (10.5)	5 (11.6)
Resource	27 (7.1)	5 (11.6)
Industrial products	81 (21.3)	11 (25.6)
Total	380 (100.0)	43 (100.0)

Table 5. Organization data according to each respondent

Industry	Respondent	Sector	Business type	No. of Employees	Company age
Service	R1	Transportation & logistics	B2B, B2C	4570	7
	R2	Transportation & logistics	B2B	296	15
	R3	Health care services	B2C	N/A	20
	R4	Tourism and leisure	B2C	11307	21
	R5	Tourism and leisure	B2B	73	6
	R6	Media and publishing	B2B	1402	7
Consumer product	R7	Fashion	B2C	487	34
	R8	Fashion	B2B	11312	23
	R9	Personal and pharmaceutical products	B2B	1680	23
	R10	Personal and pharmaceutical products	B2B, B2C	1539	5
Property and construction	R11	Property development	B2C	N/A	5
	R12	Property development	B2C	2823	16
	R13	Property development	B2C	N/A	21
	R14	Property development	B2B	1089	7
	R15	Property development	B2C	142	2
	R16	Property development	B2C	486	18
	R17	Property development	B2B	188	9

Industry	Respondent	Sector	Business type	No. of Employees	Company age
Property and construction	R18	Property development	B2B	N/A	6
	R19	Property development	B2B	N/A	2
	R20	Property development	B2B	N/A	2
	R21	Construction materials	B2C	2471	19
	R22	Construction materials	B2B, B2C	30820	36
Agro and food products	R23	Food and beverage	B2C	65206	24
	R24	Food and beverage	B2C	18036	23
	R25	Food and beverage	B2C	878	3
	R26	Food and beverage	B2C	3195	33
	R27	Agribusiness	B2B	419	17
Resources	R28	Energy and utilities	B2B, B2C	994	17
	R29	Energy and utilities	B2C	148	14
	R30	Energy and utilities	B2C	441	16
	R31	Energy and utilities	B2B	N/A	2
	R32	Energy and utilities	B2B	5199	16
Industrial product	R33	Steel	B2B	594	20
	R34	Steel	B2B	260	6
	R35	Steel	B2B	N/A	16
	R36	Industrial material and machinery	B2B	578	19
	R37	Industrial material and machinery	B2B	1822	7
	R38	Industrial material and machinery	B2B	N/A	16
	R39	Petrochemical and chemical products	B2B	93	6
	R40	Petrochemical and chemical products	B2B, B2C	202	16
	R41	Petrochemical and chemical products	B2B	1030	27
	R42	Automotive	B2B	830	6
	R43	Packaging	B2B	821	34

Table 6. Pearson's correlation coefficients between affectiveness scores and management performance (ROA and ROE)

		Affectiveness score		Sub-score			
		Winning	Average	Employee	Customer	Local community	Society
ROA	*r*	0.14	0.12	**0.30+**	0.04	0.06	0.06
	n	40	40	40	39	39	39
ROE	*r*	0.14	0.05	0.12	-0.35	0.08	0.14
	n	38	38	38	37	37	37

Note. + $p < 0.10$.

Table 7 shows Pearson's correlation coefficients between affectiveness scores and PER, PBR, and net profit margin. In Table 7, both winning score and average score were moderately correlated with PER (winning score: $r = 0.32$, $p < 0.10$; average score: $r = 0.31$, $p < 0.10$) and PBR (winning score: $r = 0.30$, $p < 0.10$; average score: $r = 0.31$, $p < 0.10$), while they were not correlated with net profit margin.

The employee sub-score was moderately correlated with PBR ($r = 0.29$, $p < 0.10$) and net profit margin ($r = 0.28$, $p < 0.10$). This finding means that the companies with

high employee sub-scores tended to have higher PBR and net profit margins. Thus, this result suggests that organizations that take employees' affects into account yield better financial performances. This result partially proves the third hypothesis that if affective management focuses on employees' affects, then ROA, PBR, and the net profit margin of the organization will improve.

The customer sub-score was significantly correlated with PER ($r = 0.36$, $p < 0.05$) and PBR ($r = 0.38$, $p < 0.05$). This result shows that companies with high customer sub-scores had higher PER and PBR. This result indicates that organizations that highly value customers' affects yield better performances, and thus supports, in part, the first hypothesis that affective management that prioritizes customers' affects will increase PER and PBR.

The society sub-score was significantly correlated with PBR ($r = 0.35$, $p < 0.05$). This result implies that management that cares about the affect on society results in high PBR, and thus partially supporting the fifth hypothesis. However, there was no support for the fourth hypothesis.

Finally, Table 8 shows the correlations between the affective scores and the size of the organizations. The size of the organization was significantly correlated with the affectiveness scores: winning score ($r = 0.40$, $p < 0.05$), average score ($r = 0.42$, $p < 0.01$), customer sub-score ($r = 0.46$, $p < 0.01$), local community score ($r = 0.40$, $p < 0.05$), and society score ($r = 0.39$, $p < 0.05$). This finding implies that larger organizations tend to recognize the importance of affective management and/or actually take into account stakeholders' affects when they made management decisions. This result supports the sixth hypothesis.

Table 7. Pearson's correlation coefficients between affectiveness scores and management performance indices related to investors' perspective (PER, PBR, net profit margin)

		Affectiveness score		Sub score			
		Winning	Average	Employee	Customer	Local community	Society
PER	*r*	**0.32**$^{+}$	**0.31**$^{+}$	0.11	**0.36***	0.07	0.22
	n	32	33	32	31	31	31
PBR	*r*	**0.30**$^{+}$	**0.31**$^{+}$	**0.29**$^{+}$	**0.38***	0.20	**0.35***
	n	36	36	36	35	35	35
Net profit	*r*	0.11	0.16	**0.28**$^{+}$	0.01	0.05	0.10
	n	40	40	40	39	39	39

Note. $+ p < 0.10$, $* p < 0.05$.

Table 8. Pearson's correlation coefficients between affectiveness scores and size of the organization

		Affectiveness score		Sub-score			
		Winning	Average	Employee	Customer	Local community	Society
Size	*r*	**0.40***	**0.42***	0.20	**0.46***	**0.40***	**0.39***
	n	34	34	34	33	33	22

Note. $* p < 0.05$.

Difference between B2B and B2C businesses

Organizations that engage in business with consumers (B2C) may be more sensitive to their influences on customers' and other stakeholders' affects than those doing business with other businesses (B2B). The affectiveness of management may have a greater impact on stakeholders of B2C than B2B businesses. Thus, the relationship between affectiveness scores and management performance indices might be different between B2B and B2C businesses. To investigate these possible differences, we further divided the responses into B2B and B2C groups and then compared them.

Table 9 summarizes the means and standard deviations of affectiveness scores and management performance indices by the business categories of B2B and B2C groups, as well as the results of t-tests between business categories. B2C businesses had higher affectiveness scores than B2B businesses: winning score (t = –2.04, p < 0.05), average score (t = –2.01, p < 0.10), local community sub-score (t = –2.55, p < 0.05), and society sub-score (t = –2.79, p < 0.01). Furthermore, B2C businesses also showed higher management performance with ROA (t = –1.75, p < 0.10) and significantly higher net profit margin (t = –2.28, p < 0.05) than B2B businesses.

Table 9. Means, standard deviations, and t-test results of affectiveness scores and management performance indices by B2B and B2C businesses

		Type of business	*n*	*M*	*SD*	*t*
Affectiveness scores	Winning	B2B	23	0.90	0.54	**–2.04***
		B2C	15	1.30	0.67	
	Average	B2B	23	69.80	9.25	**–2.01+**
		B2C	15	77.11	13.24	
Sub-scores	Employee	B2B	23	67.70	8.71	–1.18
		B2C	15	71.68	12.16	
	Customer	B2B	23	74.23	10.40	–0.88
		B2C	15	77.80	14.81	
	Local community	B2B	23	54.90	19.14	**–2.55***
		B2C	15	70.83	18.42	
	Society	B2B	23	57.40	14.60	**–2.79****
		B2C	15	72.75	19.44	
Performance indices	ROA	B2B	20	8.09	10.59	**–1.75+**
		B2C	15	14.45	10.72	
	ROE	B2B	18	6.65	25.35	–1.43
		B2C	15	16.74	11.38	
	PER	B2B	14	15.70	9.82	–0.23
		B2C	14	16.88	17.27	
	PBR	B2B	17	1.62	0.79	–1.36
		B2C	15	2.44	2.32	
	Net profit	B2B	20	-2.09	27.25	**–2.28***
		B2C	15	14.89	10.81	

Note. + p < 0.10, * p < 0.05, ** p < 0.01.

Tables 10 and 11 show the results of a correlation analysis between affectiveness scores and financial performance indices by business categories (B2B and B2C). Table 10 shows correlations between overall affectiveness scores (winning and average scores) and performance indices, while Table 11 shows correlations between stakeholder sub-scores and performance indices.

In Table 10, though not statistically significant, B2C responses showed some positive correlations between affectiveness scores and PER and PBR, while B2C responses did not. This issue is addressed later in the discussion section.

In Table 11, B2C responses showed a moderate positive correlation between employee sub-score and PER ($r = 0.47$, $p < 0.10$). In addition, although not statistically significant, B2C responses showed some positive correlations between customer sub-score and management performance indices (PER and PBR). This point will be addressed further in the discussion section.

Table 10. Pearson's correlation coefficients between affectiveness scores (winning score and average score) and management performance indices

		Affectiveness score			
		Winning score		Average score	
		B2B	B2C	B2B	B2C
ROA	*r*	0.14	0.01	–0.01	–0.07
	n	20	15	20	15
ROE	*r*	0.21	–0.13	0.01	–0.24
	n	18	15	18	15
PER	*r*	–0.05	**0.40**	0.14	**0.36**
	n	14	14	14	14
PBR	*r*	0.23	**0.37**	0.19	**0.27**
	n	17	15	17	15
Net profit	*r*	–0.01	–0.18	0.01	–0.08
	n	20	15	20	15

Table 11. Pearson's correlation coefficients between stakeholder sub-scores and management performance indices

		Sub-score							
		Employee		Customer		Local community		Society	
		B2B	B2C	B2B	B2C	B2B	B2C	B2B	B2C
ROA	*r*	0.28	0.07	–0.19	0.01	–0.07	–0.09	–0.09	–0.14
	n	20	15	20	15	20	15	20	15
ROE	*r*	0.08	–0.13	–0.20	–0.18	0.02	–0.18	0.21	–0.23
	n	18	15	18	15	18	15	18	15
PER	*r*	0.20	0.47+	0.22	0.36	–0.02	0.13	0.11	0.17
	n	14	14	14	14	14	14	14	14
PBR	*r*	0.22	0.26	0.04	0.38	0.13	0.14	0.22	0.25
	n	17	15	17	15	17	15	17	15
Net profit	*r*	0.33	0.01	–0.16	–0.08	–0.19	–0.06	–0.18	–0.13
	n	20	15	20	15	20	15	20	15

Note. + $p < 0.10$.

Discussion

This study investigated the relationship between the affectiveness of management and the management performance of organizations. The overall results suggest that if the top management of an organization considers the affective experiences of stakeholders (such as customers, employees, local community and society), then the performance of the organization appears to be better. These results support the underlying purpose of this study, i.e., to study the importance of the concept of affectiveness in management.

Scores that represented the overall affectiveness of the organization, i.e., winning score and average score, did not show statistically significant correlations with earnings indices such as ROA and ROE (Table 6), but these scores were significantly correlated with PER and PBR (Table 7). This finding implies that while the affective management concept might not have an instant impact on earnings, organizations that practice affective management are more likely to be appreciated by investors in the market. It might also be possible for a linkage between practices of affective management and performance to develop over the long term, and thus the relationship between them should be studied on the basis of a time series considering possible time delays.

It is also noteworthy that affectiveness scores (except for the employee sub-score) showed significant correlations with the size of organizations (Table 8). The larger the organization is, the more likely it is that its management recognizes the importance of considering the affective experiences of stakeholders and/or actually practices affective management. One possible reason for this could be that larger organizations often have more stakeholders than smaller ones, and thus they are required to take into consideration the influences of management decisions on stakeholders' affective experiences. Another possible reason might be that the larger organizations have a greater capacity than smaller ones to take account of stakeholders' affects in management decisions.

Customers

In terms of affectiveness scores by stakeholder categories, the positive correlations between customer sub-scores and management performance were intuitive. The results for PER and PBR showed statistically significant correlations (Table 7) while those for ROA and ROE did not (Table 6), suggesting that taking care of customers' affective experiences might have a greater direct influence on market appreciation than on instant profitability.

It is also understandable, although not statistically significant, that B2C businesses had higher correlations between financial performances (PER and PBR) and customer sub-scores than B2B businesses (Table 11). One possible explanation for the non-significant correlations could be the small number of organizations in this study. However, Table 9 illustrates that while both B2C and B2B businesses have their highest stakeholder sub-scores in the customer category, the B2C businesses showed a higher average customer sub-score than the B2B businesses. This result suggests that top

managers of B2C businesses are paying more attention and making efforts to take customers' affects into their management decision-making.

Employees

Employee sub-scores were also found to have moderate positive correlations with ROA, PBR, and net profit margin. Research has already shown that employees' positive affective experiences in the workplace lead to the development of positive behaviors such as action and cognition (Fredickson, 2003), work engagement (Stairs and Galpin, 2010), motivation (Fisher, 2010), increased productivity (Fredickson, 2003), and willingness to work overtime (Truss et al., 2006). Employees' positive experiences are known to lead to better financial performance for the organization, improve the discretionary efforts of employees (Corporate Leadership Council, 2004), raise target sales goals (Wellings, Bernthal, and Phelps, 2005), and drive more profit (Harter et al., 2002, 2010) and better earnings per share (ISR, 2006). In addition, employees' positive attitudes towards the workplace are known to lead to improved organizational performance (Fulmer, Gerhart, and Scott, 2003; Ballou, Godwin, and Shortridge, 2003). While there are a number approaches for organizations to improve the positive experiences of employees, including bottom-up approaches and making it the responsibility of middle managers, this study has emphasized the importance of the commitment of top managers to the affects of employees. The results show that the greater the extent that top management takes into account employees' affective experiences in their management decision-making, the better the performance of the organization.

Local community and society

In this study, using samples from Thailand, the local community sub-scores showed no significant correlations with performance indices, while society sub-scores showed overall positive correlations. It might be possible that the top managers who participated in this study did not pay much attention to the affective experiences of the local community. This finding is also suggested by the results that showed that the local community sub-scores were the lowest amongst stakeholder sub-scores, for both B2B and B2C businesses (Table 9). It might be expected that top management would care less about their local community than society in general because, for example, of their small population when compared with the entire country. The limited impact of the local community, in turn, may result in relatively small or delayed impacts on the management performance of the organizations, for example in terms of profitability or market valuations—valuations by local community populations may be dominated by those of the larger society, if these are indeed different.

Another possibility is the cultural background. The respondents in this study were all from Thailand. It might be possible that awareness among top management of the importance of considering stakeholders' affective experiences, especially of those other than customers and employees, has not yet matured in this country.

Evidence from European companies shows a positive relationship between financial performance and supporting local community activities (Bird et al., 2007). To address this cultural difference, international comparative studies with broader samples should be pursued in future research. It might also be interesting to investigate how the attitudes of the respondents in this study may change in the future.

Commitment to society has positive influences on financial performance (Branco and Rodrigues, 2006; McWilliam and Siegel, 2000). Branco and Rodrigues (2006) showed that CSR activities bring sustainability to the financial performances of organizations. While the results of this study accord with previous studies, this study also emphasized the importance that top managers themselves should be aware and actually commit to the affective experiences of society to improve organizational performance.

Conclusion

This study represented preliminary results regarding the relationship between awareness and practice of affective management and management performance of organizations. The overall results showed that affectiveness indices were positively correlated with performance indices, suggesting that those affectiveness indices could be good predictors of organizational performance. The results also suggest that the further promotion of the affective management concept might lead to a better appreciation by stakeholders and the market, and thus result in better management performance, i.e., growth, profitability, and the sustainability of organizations.

The limitations of this study include the following issues. First, the sample organizations are only from Thailand. Although it seems logical that a study from other cultures would reveal a similar pattern to this study, to uncover possible differences across cultures, international comparative studies with samples from a range of countries should be pursued because top management from different countries may behave differently.

Second, the performance indices employed in this study were only from one fiscal year (2010). To eliminate any possible economic anomalies in a particular year, and to analyze the long-term relations between affectiveness indices and management performance as discussed, management indices and financial data from more than one year should be used for analysis.

Third, the stakeholders in this study were limited to customers, employees, local communities, and society in general. Other categories of stakeholders, such as shareholders or business partners, may impact on organizational performance through their affective experiences. The analysis of these categories should also be included in future studies.

Fourth, as the personality of individuals relates with actions, desires, feelings, and thoughts, it is expected that the affectivity personality of top managements might result in difference in their effectiveness and attitude towards affective management. Thus, the differences in the affectivity personality of top management might be further studied in relation to their affective management practices and performances.

Finally, although this study showed evidence of correlations between affective indices and management performance indices, the mechanisms that connect them are not yet clear. Possible causal relationships should be further explored and validated with greater numbers of respondents in future studies.

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Abstract (in Polish)

Zarządzanie afektywne (ang. affective management) jest nową koncepcją zarządzania zgodnie z którą procesy decyzyjne menedżerów powinny brać pod uwagę doświadczenia emocjonalne zainteresowanych stron. Aby wykazać, że ta koncepcja może mieć pozytywny wpływ na funkcjonowanie organizacji, autorzy pracy podejmują badanie relacji zachodzącej pomiędzy afektywnością kierownictwa firmy i wskaźnikami funkcjonowania organizacji. Autorzy proponują ankietę, opartą o Kartę Afektywnego Zarządzania, dla zbadania postrzegania ważności afektywnego zarządzania i stosowanych praktyk afektywnego zarządzania wśród menedżerów. Badanie zostało przeprowadzone na próbie 43 członków ścisłego kierownictwa firm w Tajlandii. Rezultaty analizy korelacji pomiędzy wskaźnikami afektywnego zarządzania i kluczowymi wskaźnikami rentowności firmy wskazują na istnienie pozytywnego związeku pomiędzy praktykowaniem zarządzania afektywnego i rezultatami firm w zakresie ich rentowności oraz ich wartości rynkowej.

Słowa kluczowe: zarzadzanie afektywne, interesariusze, zarządzanie, wpływ, emocje, uczucia.

A Genetic Algorithm to Minimize the Total Tardiness for M-Machine Permutation Flowshop Problems

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Abstract

The m-machine, n-job, permutation flowshop problem with the total tardiness objective is a common scheduling problem, known to be NP-hard. Branch and bound, the usual approach to finding an optimal solution, experiences difficulty when n exceeds 20. Here, we develop a genetic algorithm, GA, which can handle problems with larger n. We also undertake a numerical study comparing GA with an optimal branch and bound algorithm, and various heuristic algorithms including the well known NEH algorithm and a local search heuristic LH. Extensive computational experiments indicate that LH is an effective heuristic and GA can produce noticeable improvements over LH.

Keywords: genetic algorithm, scheduling, permutation flowshop, tardiness.

Introduction

In the *permutation flowshop problem*, each of n jobs has to be processed on machines 1,…,*m* in that order. The processing times of each job on each machine are known. At any time, each machine can process at most one job and each job can be processed on at most one machine. Once the processing of a job on a machine has started, it must be completed without interruption. Also, each job must be processed in the same order at every machine. The usual objectives are the minimization of the make-span, total flow time, weighted total flow time, total tardiness, weighted total tardiness, and the

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number of jobs late (see Pinedo 2002 for a review of the general flowshop problem). This article deals specifically with the objective of minimizing the total tardiness; however, its results can be adapted to other objectives. Tardiness equals the amount by which a job's completion time exceeds its due date. Practical effects of tardiness might include contractual penalty costs and loss of customer goodwill. Koulamas 1994 provides a general review of scheduling problems with tardiness criteria.

Schedules where each job must be processed in the same order at every machine are called *permutation schedules*. For $m \leq 2$, the restriction to such schedules is harmless; however, for larger m, there might exist a general schedule that performs better than any permutation schedule (Pinedo 2002). Finding such a schedule is often computationally impractical; moreover, as discussed in Kim 1995 there are many real situations where only permutation schedules are feasible. Most approaches restrict attention to permutation schedules.

Most optimal algorithms for single machine tardiness problems combine dynamic programming or branch and bound with decomposition properties developed by Lawler 1997, Potts and Wassenhove 1982, and Szwarc 1993. Szwarc et al. 1998 employ an improved decomposition rule, which allows them to solve problems with $n = 300$. For multi-machine tardiness problems, Vallada et al. 2008 report that the literature contains only a handful of papers dealing with optimal algorithms. Kim 1995 applies branch and bound using a "backward branching" scheme. His results include a problem size reduction procedure, which sometimes yields a problem with a smaller n. More recently, Chung et al. 2006 obtain a more effective branch and bound algorithm by combining a different branching scheme with better bounds. Extensive computational experiments involving over 40,000 test problems suggest that Chung et al. 2006 can handle problems with $n \leq 20$, but often experiences difficulty for problems with larger n. This is not surprising, since the m machine permutation flow shop problem with the total tardiness objective is NP-hard for $m \geq 1$ (Pinedo 2002).

A practical way of dealing with multi-machine tardiness problems is to develop effective heuristic solutions. Kim 1993 evaluates several heuristics and recommends an adaptation of the NEH algorithm of Nawaz et al. 1993, while Armentano and Ronconi 1999 propose a tabu search heuristic, which they compare with the NEH heuristic and the optimal branch and bound algorithm of Kim 1995. See Framinan et al. 2005, Kim 1993, Ruiz and Maroto 2005, and Vallada et al. 2008 for reviews of the literature on heuristic algorithms.

This article develops a genetic algorithm heuristic for multi-machine permutation flowshop problems with the total tardiness objective. It fills a gap by providing a solution procedure for problems that are not solvable by the branch and bound algorithm of Chung et al. 2006. The genetic algorithm concept, due to Holland 1975, has been successfully applied to many combinatorial optimization problems (see Reeves 1997). For flowshop problems, Arroyo and Armentano 2005, Etiler et al. 2004, and Tang and Liu 2002, respectively, present genetic algorithms for multi-objective criteria, the makespan objective, and the total flow time objective.

How useful a heuristic solution is depends on how well it performs against an optimal solution. Although the ideal way to evaluate performance is through comparison studies, such studies are rarely reported in articles dealing with genetic algorithms for multi-machine scheduling problems, possibly because effective optimal algorithms are often unavailable. One advantage of this article is that the authors had developed the most up to date optimal algorithm for multi-machine tardiness problems and could use it to evaluate the performance of their genetic algorithm heuristic. Our numerical study finds that the genetic algorithm performs remarkably well making it a practical substitute for an optimal algorithm when $n \geq 15$.

§2 introduces notation and describes steps that precede our various algorithms. One of these steps is a local search heuristic, LH, which provides a starting solution for our genetic algorithm, GA. §3 describes GA in detail. Some of its notable features include clone removal, maintenance of two populations with immigration, and probabilistic local search, *i.e.*, each time one finds a new solution, one performs a local search with a given probability. §4 reports on a numerical study that compares the performance of GA, the branch and bound algorithm of Chung et al. 2006, and various heuristic algorithms. Finally, §5 states our conclusions.

Notation and Preliminaries

This section introduces notation and describes two steps that precede our branch and bound and genetic algorithms. The first step is a problem size reduction procedure of Kim 1995, which sometimes yields problems with reduced n that are easier to solve. The second step is a local search heuristic, LH, which extends the well-known NEH algorithm (see Kim 1993 and Nawaz et al. 1983) and outperforms the *m*-machine heuristic of Chung et al. 2002 and Chung et al. 2006. LH provides a starting solution for our genetic and branch and bound algorithms.

Notation. For $i = 1,\ldots,n$, $k = 1,\ldots,m$, and any algorithm, A, for generating a schedule, denote

p_{ik} processing time of job i on machine k,

d_i due date of job i,

g^A total tardiness under the schedule generated by A.

Next, turn to Kim's problem size reduction procedure. By Proposition 7 of Kim 1995, the completion time of all jobs is bounded above by

$$K = \min\left[\left\{\sum_{i=1}^{n} p_{i(\max)} + (m-1)\max_{1\le i\le n} p_{i(\max)}\right\}, \left\{\sum_{j=1}^{n} p_{(\max)j} + (n-1)\max_{1\le j\le m} p_{(\max)j}\right\}\right]$$

where $p_{i(max)} = \max_{1\le j\le m} p_{ij}$ and $p_{(max)j} = \max_{1\le j\le n} p_{ij}$. Jobs whose due dates exceed K have zero tardiness and can be scheduled last. Kim calls these jobs *dominated jobs*, since schedules where they precede other jobs are dominated by other schedules. This leads to the following procedure. Find all dominated jobs. Schedule them in the last available positions in ascending order of their due dates. Then delete them from the problem. Finally, reduce n and re-label jobs accordingly. Repeat until either a problem is found with

no dominated jobs or n has been reduced to 0. Let n_r denote the value of the *reduced n* obtained by this procedure. From the above analysis, there exists an optimal schedule where the deleted jobs are placed in positions n_r+1 through n in ascending order of their due dates. Given such a schedule, the total tardiness of the deleted jobs equals 0. Hence, for problems with n_r equal to 0, the EDD schedule is optimal and the optimal total tardiness equals 0. Our local search heuristic, LH, below applies when $n_r > 0$.

Our heuristic, LH, combines Kim's reduction procedure above with the procedure below, which depends on a single parameter, MAXREP. First, compute the EDD schedule. Stop if this step (or any of the steps below) yields a zero tardiness schedule. Second, compute the NEH schedule (see below). Third, starting with EDD as the initial incumbent, apply the ENS (extensive neighborhood search) algorithm of Kim 1993. ENS visits all neighbors of the current incumbent schedule, where a neighbor is obtained by interchanging a pair of jobs. If the best (in terms of the objective function) of the $n(n-1)/2$ neighbors is better than the incumbent, this best schedule becomes the new incumbent. Repeat until the best neighbor is no better than the current incumbent or the number of repetitions exceeds MAXREP. Fourth, apply ENS with NEH as the initial incumbent. Among the schedules obtained above, select the one with the smallest tardiness. Evaluating the tardiness of a schedule requires $O(mn)$ calculations. Hence, visiting all neighbors of a given schedule requires $O(mn^3)$ calculations. For the nontrivial test problems of §4, the mean computation time for LH ranged from 0.001 seconds for n = 15 to 1.3 seconds for n = 120. Note that for these test problems, replacing EDD above with the more complicated m-machine heuristic of Chung et al. 2002 and Chung et al. 2006 has a negligible effect on performance.

This section closes with a description of our implementation of the NEH algorithm. Let $\sigma = (\sigma(1),\ldots, \sigma(s))$ denote a *partial schedule* of *length* s, where $0 \le s \le n$, indicating that job $\sigma(j)$ occupies the jth position on each machine, for $1 \le j \le s$. A partial schedule of length 0 is the null schedule, and a partial schedule of length n is a complete schedule. For each job i not included in σ, define $C_i(\sigma)$ as the *makespan* of the partial schedule $(\sigma(1),\ldots, \sigma(s),i)$. The NEH algorithm constructs a sequence of partial schedules of successively increasing lengths until a complete schedule of length n is obtained. First, NEH uses a *dispatching rule* to select a job i for a partial schedule (i) of length 1. Next, for s = 1 to n - 1, NEH gets a partial schedule of length s+1 from a partial schedule of length s using three steps. The first step selects a job i not included in the partial schedule σ using the dispatching rule. The second step lists the s+2 partial schedules of length s+1 that can be obtained by inserting job i at some position in the partial schedule σ. (Job i could be inserted before job $\sigma(1)$, after job $\sigma(s)$, or between jobs $\sigma(j)$and $\sigma(j+1)$, where $1 \le j < s$.) The third step selects one of these s +2 partial schedules according to some *objective*. Our version of the NEH algorithm is different from the one in Nawaz et al. 1983, which used maximization of the total processing time $\sum_{k=1}^{m} p_{ik}$ for dispatching and minimum makespan as the objective. Following Armentano and Ronconi 1999, we use the MDD (modified due date rule) for dispatching, which selects the job i that minimizes $\max(d_r, C_i(\sigma))$. For the objective, we use minimum total tardiness with minimum makespan as a tiebreaker.

The Genetic Algorithm

Maintaining a population of solutions, genetic algorithms imitate genetic evolution. Periodically, the "fittest" members of the current population or generation breed to produce the next generation. Traits are passed on from parents to offspring in ways that resemble genetic mechanisms such as selection, crossover and mutation. The genetic algorithm stops after a finite number of generations with the best solution found as the proposed solution. For our genetic algorithm, GA, each solution or schedule s = $(s_1,s_2,\ldots,s_n)$ is an element of X, the set of all permutation of the integers 1 through *n*. For $t = 1, 2,\ldots,t_{max}$, the *t*th *generation* $S^{(t)} = \left\{\mathbf{s}_1^{(t)},\mathbf{s}_2^{(t)},\ldots,\mathbf{s}_N^{(t)}\right\} \subseteq X$, where the *population size N* is a multiple of 4 and the *maximum generation number* t_{max} is a positive integer. For $s \in X$, let *g(s)* denote the total tardiness of the schedule s. Also, let s^* denote the incumbent best schedule, i.e., the current best solution found, and let $g^*=g(s^*)$. Note that each evaluation of *g(s)* requires *0(mn)* calculations.

Under GA, initial values of s^* and g^* are provided by the local search heuristic, LH, of §2. The first generation $S^{(1)}$ consists of the schedules produced by EDD, NEH, ENS starting from EDD, ENS starting from NEH (see §2 for definitions), and *N-4* schedules chosen at random. Subsequently, for $t = 1, 2, \ldots, t_{max} - 1$, generation *t* +1 is obtained from generation *t*, using the selection, crossover, mutation, and clone removal, immigration, and local search procedures described next.

Selection. One half of generation $S^{(t)}$ is selected for breeding. Generation $S^{(t+1)}$ will then consist of these breeders and their offspring. Selection depends on two positive valued parameters, an *elitism factor*, p_{elit}, and a *spread factor*, p_{sprad}. Specifically, each $s \in S^{(t)}$ is assigned a *fitness value*, *f(s)*, as follows. If $g(s) \le g^* + p_{elit}$, then $f(s) = g(s)$; else $f(s) = g(s)(1+\varepsilon)$, where each ε is a uniform random variable on $[0, p_{sprad}/t]$ and is statistically independent of all other ε. In words, fitness equals tardiness if tardiness is within p_{elit} of the best tardiness value found; else fitness equals tardiness plus a perturbation times tardiness. (Since the objective function is to be minimized, schedules with smaller fitness values tend to be more desirable.) Solutions are ranked in ascending order of fitness with ties broken arbitrarily and the *N*/2 solutions with the smallest fitness values are selected for breeding. Specifically, for j = 1 to N/4, solutions $\mathbf{s}_{2j-1}^{(t)}$ and $\mathbf{s}_{2j}^{(t)}$ produce two offspring using the crossover operation below. Note that since p_{sprad}/t decreases with *t*, selection depends more on *g(s)* as the *generation number t* increases.

Crossover. GA employs a two point crossover to generate two offspring from two parents. This procedure requires that $n \ge 4$. First, we randomly generate two distinct integers, n_1 and n_2, strictly between 1 and *n*. Second, we obtain trial offspring as follows. If $n_1 < n_2$, offspring are generated by exchanging jobs in positions n_2 through n_1. If $n_1 > n_2$, offspring are generated by exchanging jobs outside positions n_2 through n_1. These trial offspring need not correspond to feasible schedules, since some jobs may be duplicated and others may be missing. We must correct them by replacing duplicated jobs with missing jobs. The example below illustrates how we do this.

A crossover example. Let $n = 8$, $n_1 = 3$, and $n_2 = 5$. Let parent 1 = (5,2,3,8,4,6,7,1) and parent 2 = (3,5,6,4,2,7,1,8). Then trial offspring 1 = (5,2,**6,4,2**,6,7,1), which duplicates

jobs 2 and 6, but misses jobs 3 and 8. Similarly, trial offspring 2 = (3,5,**3,8,4**,7,1,8), which duplicates jobs 3 and 8, but misses jobs 2 and 6. Note that the exchanged jobs are boldfaced. For j = 1 and 2, we correct trial offspring j by replacing its non-boldfaced duplicate jobs by its missing jobs, using the same order as parent j. Here, we replace the non-boldfaced 2 and 6 in trial offspring 1 by 3 and 8, respectively, because 3 precedes 8 in parent 1. This procedure yields offspring 1 = (5,3,**6,4,2**,8,7,1) and offspring 2 = (6,5,**3,8,4**,7,1,2).

Mutation. GA uses two methods to perform a mutation *on a solution: exchange* and *inversion*. In an exchange, one randomly generates an integer n_1, where $1 \le n_1 < n$, and then exchanges the jobs in position n_1 and $n_1 + 1$. In an inversion, one randomly generates two integers n_1 and n_2, where $1 \le n_1 < n_2 \le n$, and then reverses the order of the jobs in positions n_1 through n_2. When applied to a *population*, our mutation procedure depends on a *mutation parameter* p_{mutn}, where $0 \le p_{mutn} \le 1$, as follows. For each solution s in the population, one applies a mutation to s with probability p_{mutn}. Note that mutations are never performed when $p_{mutn} = 0$.

Clone removal. One can increase diversity by eliminating *clones* or duplicate solutions from the population. Clone removal is important because it eliminates the real possibility that all solutions in the population are the same. Checking the population for identical schedules is demanding computationally, however. To reduce computation time, our clone removal procedure compares the objective function values of schedules rather than the schedules themselves. Whenever two or more schedules have the same objective function values, we perform a mutation on all but one of them.

Probabilistic local search. One can often improve on a given solution s by examining the objective function values of all of its *neighbors*. If the smallest objective function value of the neighbors of s improves on *g(s)*, then a neighbor with the smallest objective function value replaces s. Our implementation of local search depends on a *local search parameter* p_{locs}, where $0 \le p_{locs} \le 1$, as follows. Each time a new solution is obtained in Steps 1 though 4 below, one performs a local search with probability p_{locs}. One can, of course, prevent local searches by setting $p_{locs} = 0$. Note that probabilistic local search has been used before, e.g., Ombuki and Ventresca 2004 incorporate it in a genetic algorithm for job shop scheduling.

Neighborhood definition. Under LH, the local search heuristic of §2, a neighbor of solution is defined through the exchange of an arbitrary pair of jobs, resulting in each solution having $O(n^2)$ neighbors. A pilot study, however, found that the computations for GA were too burdensome under this definition. To ensure that each solution has only $O(n)$ neighbors, GA defines neighbor *via generalized adjacent pairwise* interchanges, i.e., the interchange of jobs in any positions j and $j + l$, where $1 \le j, j + l \le n$, and $1 \le l \le k$, for some prescribed positive integer k. (This type of interchange reduces to an *adjacent pairwise* interchange when k = 1.) Since evaluating any $g(s)$ requires $O(mn)$ calculations, a local search requires $O(mn^2)$ calculations. Our pilot study found that k = 5 was effective in trading off solution quality versus computation time, so the value k = 5 is used in all of our reported results.

Other local search methods are possible. First, our method performs exactly one pass through the neighbors of s. One alternative is to perform two passes when the first pass results in an improvement. Another is to make multiple passes, stopping when a pass makes no improvement. (This is used for LH and leads to a true local optimal solution.) Second, the neighbors of s could consist of *circular rotations* of the form, $(s_k,\ldots,s_n,s_1,\ldots,s_{k-1})$, where $1 < k \leq n$. Our pilot study indicated that the solution quality and computation time trade-offs are better under our local search method and our neighborhood definition.

Termination criterion. GA stops before t exceeds t_{max} or when the number of successive generations with no improvement in the incumbent best schedule equals a stop parameter, p_{stop}, whichever occurs first. Of course, GA keeps track of the generation number t_{limp} where the last improvement occurred.

The five-step scheme below is controlled with the flag NOCLONE. This flag determines whether the clone removal operator is executed in Step 4 below. Notice that at the end of Steps 2, 3, and 4, our algorithm calls a procedure *update*. If the best solution in the current population is better than the incumbent solution, the update procedure replaces the incumbent solution with the best solution and sets $t_{limp} = t$.

Step 1. Obtain the initial population and initialize the incumbent solution. Set $t = 1$ and $t_{limp} = 0$.

Step 2. Use the selection and crossover procedures to generate a new population and call update.

Step 3. Apply the mutation procedure to the population and call update.

Step 4. If NOCLONE = TRUE, then apply the clone removal procedure and call update.

Step 5. If $t = t_{max}$ or $t - t_{limp} = p_{stop}$ then stop; else set $t = t + 1$ and go to Step 2.

Multiple populations and immigration. One way of maintaining diversity is to have multiple populations and to apply the five-step scheme above to each population. The best of the solutions obtained for the individual populations would then be the final solution. Note that given multiple populations, one also has the option of allowing or not allowing immigration between populations. GA employs two populations and incorporates the flag, IMMIGRATION, which determines whether there is immigration. If IMMIGRATION = TRUE, then the overall computations are controlled by an *periodicity parameter*, p_{perd}, as follows: Every p_{perd} periods 20% of the solutions in each population are selected at random and transferred to the other population.

In summary, GA incorporates eight parameters, N, t_{max}, p_{stop}, p_{elit}, p_{sprd}, p_{mutn}, p_{locs}, p_{perd}, together with two flags, NOCLONE and IMMIGRATION, combined with two types of mutation. Selecting options for GA entails trade-offs between the computation time and the solution quality. For example, increasing N, t_{max}, p_{locs} and p_{stop} tends to make the computation time worse and the solution quality better.

To simplify the numerical analysis of §4, we undertook a pilot study involving an extensive number of test problems with a variety of options and found several apparent trends: First, the type of mutation does not affect the average solution

quality and computation time. Second, setting NOCLONE and IMMIGRATION equal to TRUE does a good job of trading-off average solution quality and average computation time. Given these results, the test problems reported in §4 have NOCLONE and IMMIGRATION set equal to TRUE. These problems also employ only the exchange method of mutation. Our pilot study tested N = 120, 160, and 200 and p_{perd} = 20, 40, and 60 and found negligible differences in performance. Values of t_{max} up to 10000 combined with various values of, p_{stop}, p_{elit}, p_{sprd}, p_{mutn}, and p_{locs} were also tested. There seemed to be little advantage to increasing t_{max} beyond 5000 or p_{stop} beyond 400. Also p_{elit} = 0.10, p_{sprd} = 0.05, and p_{mutn} = 0.15 performed well. Therefore, the test problems of §4 employ the following values:

N = 120, t_{max} = 5000, p_{stop} = 400, p_{elit} = 0.10, p_{sprd} = 0.05, p_{mutn} = 0.15, p_{perd} = 40.

One of our striking findings is that small values of p_{locs} are effective in trading-off computation time and solution quality. Our original plan was to compare the options *never use local search* (p_{locs} = 0) and *always use local search* (p_{locs} = 1). Neither option did well in our pilot study. The first had problems with solution quality, while the second had problems with computation time. Our choice of probabilistic local search is designed to circumvent such problems. §4 performs a sensitivity analysis on p_{locs} that compares the values 0, 0.01, 0.10, and 1. Its results suggest that p_{locs} = 0.01 or 0.10 are good choices.

Numerical Study

This section reports on a numerical study that assesses the effectiveness of GA, our genetic algorithm, BB, the branch and bound algorithm of Chung et al. 2006, and LH, the local search heuristic of §2. Measuring the performance of these algorithms when n is large is not straightforward because optimal solutions are not always readily obtainable. We deal with this issue as follows. *First*, we evaluate LH by comparing it with the well known NEH algorithm, which is sometimes used as a benchmark in numerical studies (e.g., see Armentano and Ronconi 1999 and Etiler et al. 2004). Our numerical results find that LH significantly outperforms NEH, which suggests that LH is a more appropriate benchmark than NEH. *Second*, we evaluate GA and BB by comparing them with LH. *Third*, we further evaluate GA by comparing its objective function with an optimal objective function for test problems where BB provides an optimal solution. Note that most test problems with $n \leq 20$ are solved to optimality by BB.

Our test bank consists of 2160 randomly generated problems encompassing a wide variety of situations, with n assuming the values, 10, 15, 20, 30, 60, and 120. The numerical results suggest that LH is an effective heuristic and that both BB and GA can yield noticeable improvements over LH-at the cost of extra programming effort and computation time. In terms of trading-off computation time and solution quality, BB is superior to GA for n = 10 while GA is superior to BB for $n \geq 20$. When n = 15, both algorithms perform acceptably, but GA has the advantage with computation time. For large n, the solution quality under BB is much worse that under GA and not much better than under LH. Finally, a sensitivity analysis indicates that GA does well for small values of p_{locs}, the local search probability.

Turn to our problem generation procedure. All processing times are generated by the scheme of Chung et al. 2002, and Chung et al. 2006. Specifically, for i = 1,…,n and k = 1,…,m, p_{ik} has a discrete uniform distribution on [a_{ik}, b_{ik}], where a_{ik} and b_{ik} depend on a trend and a correlation factor. A positive trend in the processing time for job i indicates that p_{ik} is increasing in k, while a negative trend indicates that p_{ik} is decreasing in k. Similarly, a correlation between the processing times of job i exists if $p_{i1},…,p_{in}$ are consistently relatively large or relatively small. For problems with correlation, additional integers, r_i, i = 1,…,n, are randomly drawn from {0,1,2,3,4}. Depending on the existence of a trend and/or a correlation, we obtain the following six *p-types*.

(I) Neither correlation nor trend: a_{ik} = 1 and b_{ik} = 100.

(II) Correlation only: a_{ik} = 20 r_i and b_{ik} = 20r_i + 20.

(III) Positive trend only: a_{ik} = 12 ½ (k-1) + 1, and b_{ik} = 12 ½ (k-1) + 100.

(IV) Correlation and positive trend: a_{ik} =2½ (k-1) + 20r_i +1, and b_{ik} =2½ (k-1) +20r_i +20.

(V) Negative trend only: a_{ik} = 12½ (m-k) + 1, and b_{ik} = 12½ (m-k) + 100.

(VI) Correlation and negative trend: a_{ik} =2½ (m-k) +20r_i + 1, and b_{ik} =2½ (m-k) +20r_i +20.

Due dates are generated from the scheme of Kim 1995, which employs two parameters: a *tardiness factor* τ and a *relative due-date range* ρ. Specifically, for i = 1,…,n, d_i has a discrete uniform distribution on $\left[P(1-\tau-\rho/2), P(1-\tau+\rho/2)\right]$, where P is the following lower bound on the *makespan* (i.e., the time needed to complete all jobs):

$$P = \max_{1\le j\le m}\left\{\sum_{i=1}^{n} p_{ij} + \min_{1\le i\le n}\sum_{l=1}^{j-1} p_{il} + \min_{1\le i\le n}\sum_{l=j+1}^{m} p_{il}\right\}$$

The range and mean of d_i are approximately equal to ρP and $P(1-\tau)$, respectively. Varying τ and ρ as in Armentano and Ronconi 1999, we obtain the following four *d-types:*

(I) low tardiness factor (τ = 0.2) and wide relative due-date range (ρ = 1.2).

(II) low tardiness factor (τ = 0.2) and narrow relative due-date range (ρ = 0.6).

(III) high tardiness factor (τ = 0.4) and wide relative due-date range (ρ = 1.2).

(IV) high tardiness factor (τ = 0.4) and narrow relative due-date range (ρ = 0.6).

We use eighteen pairs of (m, n) values, i.e., all combinations of m = 2, 4, 8 and n = 10, 15, 20, 30, 60, and 120. For each (m, n), *p-type*, and *d-type*, we generate 5 problems. There are thus 2160 test problems (i.e., 120 for each m and n value).

Kim's problem size reduction procedure, described in §2, was applied to all test problems and LH was applied to all problems where n_r, the reduced n, was positive. Problems with n_r < 8 are easily solved by BB, but are too small for GA handle. Also LH is automatically optimal if g^{LH} = 0. Therefore, classify a problem as active if $n_r \ge 8$ and > 0. Among our 2160 test problems, 1513 were active, 269 had < 8, and 378 had 8 and g^{LH} = 0. BB and GA were applied to the active problems, with LH yielding the initial incumbent.

GA was coded in Fortran 90 and run under Compaq Visual Fortran version 6.1 on a 2.4 Ghz Pentium 4 under Windows XP; BB, LH, and NEH were coded in C and run

under Microsoft Visual C++ version 6.0 under Windows XP. All random numbers were generated by the *ran1* procedure from Press et al. 1992. The parameter MAXREP of LH was set to 120. BB *stopped prematurely* whenever the node count reached a specified *stop number* M-with a schedule that might or might not be optimal. We tried several values of *M*, since it strongly affects the computation time and the solution quality of BB. Initially, we applied BB to all active problems after setting $M = 10^7$ for n = 10, 15, 20, and 30 and setting $M = 4 \cdot 10^6$ for n = 60 and 120. This led to optimal solutions whenever n = 10. Next, we resolved the problems with n = 15 and n = 20 after setting $M = 2 \cdot 10^7$. This resulted in 94.3% of problems with n = 15 and in 43.6% of problems with n = 20 being solved to optimality. Then, we performed additional computations in which all of the problems with n = 15 where BB stopped prematurely were solved to optimality by setting $M = 2 \cdot 10^9$. Among these 44 problems, 8 had their objective functions improved. (The other 36 were already optimal.)

The hardest problem took 1.44 hours and had a node count of 1.2 billion. All these computations together with all the computations for LH and NEH were performed on a 3.0 Ghz Pentium D. The remaining computations described next were arduous. They were run on several Pentium computers several with clock speeds ranging from 1.7 Ghz to 3.0 Ghz, which must be taken into account when comparing computation times. First, to better depict optimal solutions, we resolved the problems with n = 20 after setting $M = 4 \cdot 10^8$. This resulted in 63.7% of problems being solved to optimality. Second, we resolved problems with n = 30 after setting $M = 2 \cdot 10^7$and problems with n = 60 and 120 after setting $M = 10^7$. Incidentally, these changes in M greatly increased the mean computation time for BB, but had only a small effect on the average solution quality.

Active test problems can be classified according to whether *BB succeeds* in finding schedule which is known to be optimal or *BB stops prematurely* with a schedule that might be suboptimal. Table 1 reports on the number of test problems in each classification as a function of n and d-type (using the largest *M* values employed, i.e., $M = 10^7$ for n = 10, $M = 2 \cdot 10^9$ for n = 15, $M = 4 \cdot 10^8$ for n = 20, $M = 2 \cdot 10^7$ for n = 30, and $M = 10^7$for $n \geq 60$). Notice that d-type I and II problems are less likely to be active than d-type III and IV problems, especially as n increases. In particular, when n = 120, almost none of the d-type I and II problems and almost all of d-type III and IV problems are active.

All tables, but Table 1, deal with the 1513 active test problems. Table 2 reports on the number of active problems and the percent where BB stopped prematurely versus n and M. Notice that for the largest M values employed, BB stops prematurely for 0%, 0%, 36.3%, 83.0%, 89.5%, and 88.8% of the active test problems when n = 10, 15, 20, 30, 60, and 120, respectively. Note that the test problems of this article are harder than those of Chung et al. 2006, as shown by the percentage of problems where BB stops early.

Tables 3, 4, and 5 list the mean and standard deviations of the computation times of LH versus n, BB versus n and M, and GA versus n and ρ_{locs}, respectively, for the active test

problems. Notice that the standard deviation values in these and other tables tend to be high relative to the mean values, reflecting the high degree of variability. The mean computation times for LH are much smaller than the mean computation times for GA and BB, but tend to increase rapidly with *n*. For large *n*, one might want to reduce the times for LH by making the parameter MAXREP smaller and redefining neighborhood along the lines of §3 in order as to get $O(n)$ instead of $O(n^2)$ neighbors for each schedule and this bring the number of calculations for LH down from $O(mn^3)$ to $O(mn^2)$.

Table 1. Number of problems in each classification vs. n and d-type (using highest M values for BB)

Classification	d-types I and II						d-types III and IV						Row Total
	n						*n*						
	10	**15**	**20**	**30**	**60**	**12**	**10**	**15**	**20**	**30**	**60**	**120**	
$n_r < 8$	13	16	25	33	74	100	1	2	1	2	0	2	269
$n_r \geq 8$ and	31	40	58	73	85	78	1	2	3	5	1	1	378
BB stops normally	136	124	44	15	1	0	178	176	130	27	20	20	871
BB stops prematurely	0	0	53	59	20	2	0	0	46	146	159	157	642
Column Total	180	180	180	180	180	180	180	180	180	180	180	180	2160

Table 2. Number of active problems and % where BB stopped prematurely vs. *n* and *M*

n	Active problems	% stopped				
		$M = 4 \cdot 10^6$	$M = 10^7$	$M = 2 \cdot 10^7$	$M = 4 \cdot 10^8$	$M = 2 \cdot 10^9$
10	314	-	0	-	-	-
15	300	-	9.0	5.7	-	0
20	273	-	60.8	56.4	36.3	-
30	247	-	85.4	83.0	-	-
60	200	90.0	89.5	-	-	-
120	179	91.1	88.8	-	-	-

Table 3. Computation times for LH in seconds

n = 10		*n = 15*		*n = 20*		*N = 30*		*n = 60*		*n = 120*	
mean	s.d.	mean	s.d.	mean	s.d.	Mean	s.d.	mean	s.d.	mean	s.d.
0.0002	0.002	0.001	0.004	0.002	0.005	0.010	0.011	0.118	0.122	1.287	1.549

Table 4. Computation times for BB in seconds

n	$M = 4 \cdot 10^6$		$M = 10^7$		$M = 2 \cdot 10^7$		$M = 4 \cdot 10^8$		$M = 2 \cdot 10^9$	
	mean	**s.d.**	**mean**	**s.d.**	**mean**	**s.d.**	**mean**	**s.d.**	**mean**	**s.d.**
10	-	-	0.01	0.03	-	-	-	-	-	-
15	-	-	17.5	34.7	23.8	52.0	-	-	57.7	322.9
20	-	-	166.2	160.9	311.3	314.4	3683.7	4762.1	-	-
30	-	-	448.6	313.1	1808.8	1530.2	-	-	-	-
60	717.0	617.6	1887.2	1765.1	-	-	-	-	-	-
120	2688.6	2526.0	6725.2	6575.7	-	-	-	-	-	-

Table 5. Computation time for GA in seconds

n	ρ_{locs} = 0		ρ_{locs} = 0.01		ρ_{locs} = 0.10		ρ_{locs} = 1	
	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
10	3.3	0.8	3.4	0.8	4.6	1.2	15.4	5.4
15	4.5	1.2	4.8	1.3	8.2	2.7	37.6	17.0
20	6.1	2.2	7.1	2.8	14.5	6.8	77.5	40.1
30	9.9	5.7	13.0	6.7	37.0	23.5	239.4	140.9
60	24.7	23.3	52.6	46.9	277.6	268.3	2010.6	1801.4
120	49.1	58.4	317.9	424.9	2509.3	3561.1	-	-

Table 6. π *(NEH, LH)*

n = 10		*n = 15*		*n = 20*		*n = 30*		*n = 60*		*n = 120*	
mean	s.d.	Mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
-11.1	40.5	-25.1	103.5	-34.8	218.8	-50.4	235.2	-37.2	135.1	-20.1	61.9

source: authors' elaboration

Table 7. % of cases where $g^{LH} < g^{NEH}$

n = 10	*n = 15*	*n = 20*	*n = 30*	*n = 60*	*n = 120*
59.9	68.0	80.2	89.9	89.0	89.9

Table 8. π *(BB, LH)*

n	*M = 4·10⁶*		*M = 10⁷*		*M = 2·10⁷*		*M = 4·10⁸*		*M = 2·10⁹*	
	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
10	-	-	1.8	9.2	-	-	-	-	-	-
15	-	-	3.7	12.2	3.7	12.2	-	-	3.8	12.2
20	-	-	3.7	11.0	3.9	11.4	4.7	12.3	-	-
30	-	-	2.0	10.1	2.1	10.1	-	-	-	-
60	0.5	3.9	0.5	3.9	-	-	-	-	-	-
120	0.01	0.1	0.03	0.2	-	-	-	-	-	-

Table 9. π *(GA, LH)*

n	ρ_{locs} *= 0*		ρ_{locs} *= 0.01*		ρ_{locs} *= 0.10*		ρ_{locs} *= 1*	
	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
10	1.7	9.2	1.6	8.2	1.8	9.2	1.8	9.2
15	3.0	11.2	3.5	11.7	3.7	12.2	3.7	12.2
20	3.2	10.1	4.6	11.3	5.3	12.9	5.3	13.0
30	3.8	12.9	6.8	16.7	7.8	17.8	8.4	18.7
60	2.9	11.4	7.3	16.6	8.2	17.3	8.6	17.5
120	1.6	7.9	3.9	10.6	4.5	11.6	-	-

Table 10. % of cases where selected algorithms outperform one another

n	M	$g^{BB} < g^{LH}$	$\rho_{locs} = 0$			$\rho_{locs} = 0.10$		
			$g^{GA}<g^{LH}$	$g^{GA}< g^{BB}$	$g^{BB}< g^{GA}$	$g^{GA}<g^{LH}$	$g^{GA}< g^{BB}$	$g^{BB}< g^{GA}$
10	10^7	23.9	22.9	0	1.9	23.9	0	0
15	10^7	38.7	32.3	0	14.0	39.3	0.7	1.3
15	$2{\cdot}10^9$	39.3	32.3	0	14.7	39.3	0	13.3
20	$2{\cdot}10^7$	46.5	45.4	11.0	22.3	56.4	19.0	3.7
20	$4{\cdot}10^8$	52.7	45.4	4.0	26.4	56.4	7.7	4.4
30	$2{\cdot}10^7$	23.9	55.1	42.1	12.1	73.7	60.3	1.2
60	$4{\cdot}10^6$	4.0	55.3	54.2	0.6	78.0	74.5	0
120	$4{\cdot}10^6$	1.7	45.3	43.6	0.6	81.0	79.3	0

Table 11. % of problems where BB stops normally and $\pi^*(GA)$ when BB stops normally

n	M	% stopped normally	$\pi^*(GA)$							
			$\rho_{locs} = 0$		$\rho_{locs} = 0.01$		$\rho_{locs} = 0.10$		$\rho_{locs} = 1$	
			Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
10	10^7	100	0.1	0.7	0.3	4.2	0	0	0	0
15	$2{\cdot}10^9$	100	1.1	7.1	0.3	2.9	0.05	0.6	0.01	0.1
20	$4{\cdot}10^8$	63.7	2.5	9.2	1.2	7.3	0.1	0.9	0.01	0.1
30	$2{\cdot}10^7$	17.0	0.4	1.3	0.1	0.6	0.05	0.2	0.02	0.1
60	10^7	10.5	2.6	10.3	0	0	0	0	0	0
120	10^7	11.2	0.01	0.04	0	0	0	0	-	-

Turn to BB and GA. For n = 10, the mean computation time under BB is much smaller than under GA, while for $n \geq 20$, the mean computation times for GA tend to be much smaller than for BB-especially when ρ_{locs} is small. Notice that the mean computation times for GA in Table 5 appear to grow linearly with n when $\rho_{locs} = 0$ and quadratically in n when $\rho_{locs} > 0$. This is not surprising since each evaluation of the tardiness function, $g(s)$, requires $O(mn)$ calculations, while each local search for GA search requires $O(mn^2)$ calculations. As discussed later in this section, our numerical results indicate that small values of ρ_{locs} are effective in trading-off computation time and solution quality.

The remaining tables deal with the solution quality of our algorithms on active test problems. In general, one can evaluate the solution quality of a schedule by comparing it with a benchmark schedule or with an optimal schedule-when an optimal schedule is obtainable. Our benchmark schedule is the one produced by LH and our criterion is the percentage average measure defined below. This measure is appropriate when the goal is to minimize a nonnegative objective function.

Define the *percentage advantage of algorithm* A over LH by

$$\pi(A,LH) = 100(g^{LH} - g^{A}) / g^{LH} \quad (4.1)$$

For active test problems, g^{LH} is positive so (4.1) is defined. The quantity $\pi(A,LH)$ represents the difference between g^{LH} and g^{A} expressed as a percentage of g^{LH}. Tables

6, 8, and 9 evaluate the solution quality of NEH, BB, and GA on active test problems using $\pi(NEH, LH)$, $\pi(BB, LH)$, and $\pi(GA, LH)$, respectively. Note that NEH provides a starting solution for LH, and LH provides a starting solution for BB and GA. Hence, $g^{LH} \leq g^{NEH}$, $g^{BB} \leq g^{LH}$, and $g^{GA} \leq g^{LH}$, implying that $\pi(NEH, LH) \leq 0$, $\pi(BB, LH) \geq 0$, and $\pi(GA, LH) \geq 0$ for active test problems.

Similarly, define the percentage advantage of an optimal solution over A by

$$\pi^*(A) = \begin{cases} 0, & \text{if } g^A = g^*, \\ 100\left(g^A - g^*\right)/g^A, & \text{if } g^A > g^*, \end{cases} \tag{4.2}$$

where g^* denotes the optimal total tardiness. Note that (4.2) is always defined since $g^* \geq 0$, implying that $g^A > 0$ when $g^A > g^*$. The quantity $\pi^*(A)$ represents the difference between g^A and g^* expressed as a percentage of g^A. When BB stops normally, $g^* = g^{BB}$, so one can obtain $\pi^*(A)$. Table 11 uses $\pi^*(GA)$ to evaluate how close GA is to optimality on the set of test problems where BB stops normally.

Comparing LH with NEH, Table 6 reports on the mean and standard deviation of, $\pi(NEH, LH)$, the percentage advantage of NEH over LH versus n, while Table 7 reports on the percentage of cases where $g^{LH} < g^{NEH}$ versus n. These tables indicate that the solution quality under NEH tends to be much worse that under LH. For instance, when n = 60, the mean value of $\pi(NEH)$ equals -37.2, i.e., on the average g^{NEH} is 37.2% larger than g^{LH}; furthermore, $g^{LH} < g^{NEH}$ in 89.0 % of the cases. To verify that the differences between LH and NEH in Tables 6 and 7 also hold for large n, we generated additional test problems for n = 180, 240, and 300, using the same scheme as before, and got results similar to those for n = 120. These results suggest LH is a more appropriate benchmark than NEH when evaluating algorithms.

Table 8 compares BB with the LH by reporting in the mean and standard deviation of $\pi(BB, LH)$ versus n and M. Similarly, Table 9 compares GA with LH by reporting in the mean and standard deviation of $\pi(GA, LH)$ versus n and ρ_{locs}. Notice that GA does much better than LH for all n tested, while BB does substantially better for small n only. Indeed, BB does only slightly better than LH when n is large, the mean percentage advantage equaling 0.5% for n = 60 and 0.03% for n = 120 for the largest M employed. These small values for large n might be due to BB often stopping prematurely.

Table 10 reports on the percent of cases where GA and BB outperform LH, GA outperforms BB, and BB outperforms GA for selected values M and for ρ_{locs} = 0 and 0.10. Notice that $g^{GA} = g^{BB}$ for all test problems when n = 10, $M = 10^7$ and ρ_{locs} = 0.10. Since BB is always optimal those problems, GA must also be optimal. The results in Table 10 are more favorable to BB over LH when when n = 60 or 120 than the results in Table 8; however, when BB does better than LH, the difference tends to be small. For example, consider the cases reported in Tables 8 and 10 where n = 120 and $M = 4 \cdot 10^6$. There, BB outperforms LH in 1.7% of the problems, but the average difference in the percentage advantage over NEH is only 0.01%.

Turn to a comparison of GA and BB. As indicated in the analysis of the various cases below, our numerical results indicate that BB is better for small *n* and GA is better for moderate and large *n*.

The case n = 10: As mentioned above, BB and LH obtain optimal schedules for all problems when M = 10^7 and ρ_{locs} = 0.10; however, BB is the clear winner, since its mean computation time of 0.01 seconds is far superior to GA's mean computation time of 4.6 seconds. (Both times are acceptable, however.)

The case n = 15: In terms of average solution quality, BB with $M = 10^7$ and LH with ρ_{locs} = 0.10 do equally well, with mean relative advantages over LH of 3.7% in Tables 8 and 9. Nevertheless, GA with a mean time of 8.2 seconds seems to be the winner over BB with a mean time of 17.5 seconds. On the other hand, BB can obtain optimal solutions for all test problems (with, however, an increase in the mean time to 57.7 seconds and only a 0.1% improvement in the mean relative advantage over LH).

The case n = 20. In terms of average solution quality and computation time, GA with ρ_{locs} = 0.10 does better than BB for any of the *M* values tested, i.e., the mean values of $\pi(GA, LH)$ in Table 9 are greater than the mean values of $\pi(BB, LH)$ in Table 8, and the mean times for BB in Table 4 are greater than the mean times for GA in Table 5.

The case n ≥ 30. In terms of average solution quality and computation time, GA with ρ_{locs} = 0.01 does much better than BB for any of the *M* values tested. Furthermore, for $n \geq 60$, the mean values of $\pi(BB, LH)$ are close to 0 and BB never outperforms GA when ρ_{locs} = 0.10 (see Tables 8 and 10).

Table 11 reports on the percent of test problems where BB stops normally versus *n*, and the mean and standard deviation of $\pi^*(GA)$, the percentage advantage of an optimal solution over GA, versus *n* and ρ_{locs}. In order to maximize the number of problems where BB stops normally and thus g^* is available, Table 11 utilizes the largest value of *M* employed by BB. For *n* = 10 and 20, all problems are solved to optimality by BB, and GA is almost as good as BB when $\rho_{locs} \geq 0.01$. For *n* = 20, 63.7% of the problems are solved to optimality, and the average solution quality of GA is good for ρ_{locs} = 0.01 and outstanding for $\rho_{locs} \geq 0.10$. Finally, for $n \geq 30$, between 10% and 17% of the problems are solved to optimality by BB and GA is almost as good BB for such problems when $\rho_{locs} \geq 0.01$. For problems where $n \geq 30$ and BB stops prematurely, the superior performance of GA indicates that on the average BB is not close to optimality; however, the average closeness of GA to optimality is unknown.

The parameter ρ_{locs} strongly affects the computation time and the solution quality of GA. One of our more interesting findings is that small values of ρ_{locs} are effective in trading-off computation time and solution quality. Tables 5 and 9 perform a sensitivity analysis on ρ_{locs} that examines computation time and the solution quality of GA for ρ_{locs} = 0, 0.01, 0.10, and 1. As expected, both computation time and solution quality tend to increase with ρ_{locs}. The data suggest that ρ_{locs} = 0.01 and ρ_{locs} = 0.10 are effective choices.

Incidentally, the entries for $n = 120$ and ρ_{locs} = 1 are missing from Tables 5 and 9. A sample of over 100 test problems found that increasing ρ_{locs} from 0.10 to 1 when $n = 120$ increased the mean of $\rho(GA, LH)$ by under 0.5%, while greatly increasing

computation times. (Many test problems took over 24 hours to solve.) Also, observe that in the row for n = 10 of Table 9, the mean of $\rho(GA, LH)$ is smaller for ρ_{locs} = 0.01 than for ρ_{locs} = 0, illustrating that $\rho(GA, LH)$ is not always a nondecreasing function of ρ_{locs}.

Conclusions

The m-machine, n-job, permutation flowshop problem with the total tardiness objective is a common scheduling problem, known to be NP-hard. Branch and bound, the usual approach to finding an optimal solution, experiences difficulty when n exceeds 20. This article fills a gap by providing a solution procedure for problems that are not solvable by the branch and bound algorithm of Chung et al. 2006, developing a genetic algorithm, GA, which can handle problems with larger n. GA incorporates clone removal, two populations with immigration, and probabilistic local search. We also undertake a numerical study comparing GA with an optimal branch and bound algorithm BB, and various heuristic algorithms, including the well known NEH algorithm and a new heuristic LH.

One critical advantage of this article is that the authors had developed the state of the art optimal algorithm for multi-machine tardiness problems and could use it to evaluate the performance of their algorithms. Extensive computational experiments indicate that LH is an effective heuristic and GA can produce noticeable improvements over LH. Furthermore, GA seems to do a much better job than BB of trading-off computation time and solution quality for $n \geq 15$, and the solution quality under BB is not noticeably better than under LH for large n. One striking result is that GA appears to do well for small values of the local search probability.

For future research, we believe that the following topics are potentially useful: (i) the application of other solution techniques to the problem, e.g., Lagrangean relaxation and slack variable decomposition; (ii) extending GA to other objectives, e.g., total weighted tardiness, total flowtime, total weighted flowtime, and makespan.

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Abstract (in Polish)

Permutacyjny problem przepływowy (ang. permutation flowshop problem) z m maszynami i n zadaniami oraz minimalizacją sumy opóźnień jest znanym zagadnieniem z zakresu szeregowania zadań. Zagadnienie to należy do kategorii NP-trudnych problemów optymalizacji kombinatorycznej. Metoda podziału i ograniczeń (ang. branch and bound), popularne podejście do rozwiązania problemu, doświadcza trudności (biorąc pod uwagę czas potrzebny dla znalezienia rozwiązania optymalnego) gdy n przekracza 20. W niniejszej pracy, proponujemy algorytm genetyczny GA dla rozwiązywania zagadnienia dla dużych wartości n. Przytaczamy wyniki obszernego studium obliczeniowego, które porównuje fukcjonowanie algorytmu GA z metodą podziału i ograniczeń oraz metodami heurystycznymi - znanym algorytmem NEH i heurystyką lokalnego przeszukiwania LH. Rezultaty obliczeniowe wskazują, że metoda LH jest wydajnym algorytmem heurystycznym i że metoda GA oferuje możliwość poprawy wyników w porównaniu z algorytmem LH.

Słowa kluczowe: algorytm genetyczny, planowanie, permutacja, opóźnienia.

Transferability and Commercialization of Patent Rights: Economic and Practical Perspectives

Haim V. Levy*

Abstract

The transformation of innovation into commercial value depends primarily on appropriate protection of the intellectual property, usually by patents, and efficient pathway(s) of its transferability as well as the transfer of the protected knowledge. The key features of patents, from an economic perspective, are that they encompass new knowledge and confer monopoly rights to the owner. The exclusiveness of patent rights is generally conceived as a necessary mechanism to ensure further innovation, stimulate advanced research and facilitate efficient market transactions with patent rights. The patent holder can transfer the technology embodied by way of granting to others a license to use the patented invention in return for a share of the revenues, usually royalties. Patent rights transferability has been proven to be efficient and profitable to the industry as well as beneficial to the welfare of society. The economic and practical perspectives of the transferability and commercialization of patent rights are discussed.

Keywords: blocking patents, cross-licensing, exclusion right, intellectual property rights, innovation, knowledge, licensing, patents, patent pools, technology transfer, transferability.

Introduction

In general, the mobility of knowledge or innovation, including from universities and research institutes, to industry is described as *'technology transfer'*[1]. I have indicated elsewhere that the exclusive nature of intellectual property rights is conceived to be essential and instrumental for efficient exchange transactions (Levy, 2011). I have further indicated that knowledge can be non-excludable since once it is made public,

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1 *More practically, technology transfer is defined, in economic terms, as the process by which a developer of knowledge or technological innovation and owner of intellectual property rights avails it to a business partner for more efficient commercial exploitation.*

in the absence of clearly defined and protected property rights, users cannot be prohibited from using it. The most common way of excluding knowledge is by patent protection. Therefore, many companies, particularly the large ones, have a decisive patent strategy aimed at protecting their proprietary technology thus giving their products an advantage over competing products.

Licensing of intellectual property rights can successfully and effectively bring protected innovation through to the market place. Efficient licensing transactions are dependent, among others, on the economic strength of the licensee, which is required to be financially, technologically and operationally competent to develop, manufacture and market innovation.

It is apparent that the transfer of property, in general, is a crucial driving force in a market economy. Correspondingly, the ability of a society to produce and commercialize knowledge (innovation) is critical for sustained economic growth and improved quality of life. Notably, the transformation of knowledge or innovation into commercial value depends primarily on its appropriate protection and successful transfer and acquisition.

This paper ensues the previous one (Levy, 2011) discussing the 'transformation of basic research into commercial value'. It is aimed at elaborating on the economic and practical perspectives of the transferability and commercialization of intellectual property rights, in particular scientific achievements and technological innovation.

Theoretical and Economic Analysis of Tangible and Intangible Property Rights

The consequence of property rights is well established in economic theory literature. However, they are defined inconsistently in the economics literature and economists sometimes define property rights in ways that diverge significantly from the conventional legal paradigm. See, for example, (Cole & Grossman, 2000).

In their fundamental paper in law and economics school, Calabresi and Melamed present a framework which basically describes all legal transferable[2] entitlements as protected by either *Property rules* or *Liability rules* (Calabresi & Melamed, 1972). An entitlement to private property is protected by property rules (decided by a government agency) to the extent that one cannot remove such entitlement without paying the value decided and agreed upon by the holder itself, *ex-ante*. Most real estate, for example, is protected by this class of entitlement.

To the contrary, entitlements protected by liability rules allow non-holders to infringe or transfer an entitlement as long as that they adequately compensate it *ex-post*, on the basis of damages determined by court[3]. Liability rules are beyond the scope of this paper and are thoroughly discussed in the literature[4]. In this paper I limit the discussion to property rules with implication on intellectual property rights.

2 Non-transferrable entitlements are protected by Inalienability rules.

3 Note that common contract law provides another example of a liability rule whereby parties to a contract can breach it, so long as they pay ex-post court-determined damages (or by alternative dispute resolution (e.g., arbitration, mediation approach).

4 For suggested reading, see e.g., (Coase, 1960); (Calabresi & Melamed, 1972); (Kaplow & Shavell, 1996); (Cole & Grossman, 2000).

In the economic literature, the term *"property right"* carries an additional meaning implying the ability of the holder to gain from its property, by consumption or exchange. Barzel has designated it as *"Economic Property Right"* (Barzel, 1977), as opposed to *"Legal Property Right"*, discussed above. Transaction cost is closely associated with the economic property right, and encompasses transfer, capture and protection of the property right. In order that the rights to a property complete or become perfectly delineated, both the holder of the right and the party interested in the property right must possess complete information on its attributes. Availability of complete information facilitates the transfer of the entitlement to be readily consummated. Evidently, high transaction cost would prohibit the transfer of the property right. In practice, there are positive transaction costs, thus the allocation and implication of entitlement is significant as it can ultimately affect social product.

The above introductory discussion on property rights is applicable, to the extent described below, also to intangible property. Intangible or intellectual property rights are defined by The Convention Establishing the World Intellectual Property Organization (WIPO)[5] as follows: *"Intellectual Property shall include rights relating to literary, artistic and scientific works; performances of performing artists, phonograms and broadcasts; inventions[6] in all fields of human endeavor; scientific discoveries[7]; industrial designs; trademarks, service marks and commercial names and designations; protection against unfair competition; and all other rights resulting from intellectual activity in the industrial, scientific, literary or artistic fields".*

In this paper I purposely limit the discussion to inventions, which are usually protected by patents. A patent is an intellectual property right granted by a national government agency to an inventor to exclude others from making, using, offering for sale, or selling the invention throughout the country or importing the invention into the country for a limited time in exchange for public disclosure of the invention when the patent is granted. Patents are therefore valid in individual countries for specified periods, usually for twenty years[8]. They are generally granted by a national patent office or a regional one like the European Patent Office (EPO)[9].

Interestingly, the origin of modern patent law can be traced to the late sixteenth century. Monopoly grants were issued through a royal legal device known as a *"letter*

5 Concluded in Stockholm on July 14, 1967 (Article 2(viii))

6 "Inventions are new solutions to specific technical problems. Such solutions must, naturally, rely on the properties or laws of the material universe (otherwise they could not be materially or "technically" applied), but those properties or laws need not be properties or laws "not hitherto recognized." An invention puts to new use, to new technical use, the said properties or laws, whether they are recognized ("discovered") simultaneously with the making of the invention or whether they were already recognized ("discovered") before, and independently of, the invention". (Cited from: http://www.wipo.int/export/sites/www/about-ip/en/iprm/pdf/ch1.pdf)

7 Scientific discoveries are not the same as inventions. The Geneva Treaty on international Recording of Scientific Discoveries (1978) defines a scientific discovery as "the recognition of phenomena, properties or laws of the material universe not hitherto recognized and capable of verification" (Article 1(1)(i))

8 The claimed invention appears to be novel, to involve an inventive step (to be non-obvious), and to be industrially applicable (Utility) [see e.g., United States Code Title, Chapter 10, Sections 35 U.S.C. 101-103; Patents Patent Cooperation Treaty - PCT Article 33(1)-(4)].

9 http://www.epo.org/index.html

patent"[10] (for further reading see e.g., (Mossoff, 2001)). Two-hundred years later, patents became explicit legal tools for promoting and protecting an inventor's property right in his or her creation. Nowadays, it is beyond doubt that patents are property rights as patents secure only the right to exclude[11] - *ius excludendi alios*. This is derived from a conception of property in land and other tangible property interest, and became the standard definition of legal entitlements in property comprising a right to exclude[12].

Patent scholars have adopted the exclusion concept of property in land, and to a certain extent to chattels, and have similarly redefined the patent law[13]. Chisum states that *"a patent grants to the patentee and his assigns the right to exclude others from making, using, and selling the invention. …It does not grant the affirmative right to make, use or sell…*." (Chisum, 2006). Markedly, unlike other forms of property, a patent includes only the right to exclude and no other rights, see, for example, (Merges & Duffy, 2007); while property rights pertaining to land and chattels secure the traditional *"bundle of rights"*[14]. Apparently, patents are conceptually differentiated from land because of seemingly important doctrinal differences between the enforcement of tangible and intangible property entitlements (Wlaterscheid, 2005).

The validity of the exclusion doctrine of patents may be demonstrated in the phenomenon of *'blocking patents'*. A blocking patent exists when two separate patents cover aspects of the same invention, and thus each patentee can exercise their right to exclude the other patentee from using their respective contribution to this invention[15] (see also discussion on cross-licensing and patent pools in Section 3, below). Such situations are quite common, thus prior inventors are able to exclude consequent commercial applications of their inventions. Some scholars however tend to view the blocking patent scenario as evidence of the distinction between property and exclusive patent rights (Mossoff, 2009). Notably, there is no parallel example to the blocking patent in the domain of tangible property, which is why blocking patents are cited as evidence of the conceptual distinctiveness of patents as property.

It should be mentioned that the exclusion concept of patents and its influence on modern patent doctrine has been criticized in the literature. Mossoff, for instance, suggests reconsidering both the substance and significance of the conceptual analysis

10 "The crown's prerogative to issue letters patent was a central tool in bestowing privileges upon individuals in the furtherance of royal policies."

11 The right to exclude is also interpreted as allowing the owner that alleges patent infringement to ask before a court not only damage compensation but also remedies that aim at stopping the infringing activity, mainly, injunctive relief. In a way, it is similar to land boundaries and trespass.

12 For example, as promulgated within The American Patent Act 1952.

13 Note that I purposely mostly refer to the abundant literature and scholars views vastly available with respect to the common law and the American patent law.

14 i.e., the right to exclude; the right to transfer; and the right to possess and use.

15 For example, say inventor A discovered a new drug X and was granted a patent; inventor B discovered a process to make X and was granted a patent on the process. Inventor A can exercise its right to exclude inventor B from making the drug X. In this situation, A has a "blocking patent," because it can block B to use of its own patented process. A seems to have a greater scope of exclusivity as it can produce the drug in a different process, if available, without infringing B's patent.

of patents as property (Mossoff, 2009). The question whether an intellectual property right is actually more than an 'exclusion right' is worthy to be briefly considered, in particular vis-à-vis the ownership and transferability of the intellectual property right, which is the subject matter of this paper. In brief, legal positivism arguments suggest that creators, in addition to their copyright, may be entitled to a reward based on a *'moral right'*. European and other intellectual property laws convey a "moral right" to creators in connection with the 'commercial' copyrights; see, for instance, French copyright law. I reason that the necessity for an additional moral right is to complement the economic property right[16] (which entitles the creator to gain from the protected right) with what I define as a *'social property right'*, aimed at additionally entitling the creator with recognition by society and dignity, for example, a book will always bear the name of the author[17]. Contrary to the property right, the moral right is not and should not be transferrable. It should be pointed out that 'moral right' is uncommon in patent treaties[18]. To this end, I propose to consider a 'moral right' in context of economic property right, which is virtually protected by patents. This concept will be discussed in a forthcoming paper.

The key features of patents, from economic perspectives, are that they encompass new knowledge and they confer monopoly rights to the owner that arise from the right to exclude. The patent related monopoly right is controversial and vastly discussed in the literature, see, for instance, (Kaplow, 1984); (Posner, 2005); (Nordlin & Levine, 2008)). It is worth noting that modern antitrust policy follows the general prohibition of monopolies while modern patent law succeeded the exemption. The conflict between antitrust law and patent policy has persistently perplexed jurists. It has been argued that the monopoly right purpose is to ensure further innovation and knowledge which are critical for sustained economic growth and improved quality of life and welfare. Posner distinguishes between *'legal'* and *'economic'* monopoly. A legal monopoly is not necessarily an economic monopoly. It is evident to assume that a patent can be used as a lever to obtain power over the price of unpatented products that are complements of the patented products. Furthermore, patented products do not confer a power over the price of substitutes, which are not patented products (Posner, 2005). Others argue against intellectual property monopoly suggesting that monopolies work to move the wealth to the monopolists, most easily accomplished by blocking innovation and productivity growth as monopolists will do everything necessary to retain their profits (Nordlin & Levine, 2008)[19].

16 Arising from the exclusion right

17 From legal perspectives infringing the moral right may entitle the creator to compensation, that in addition to damages for the infringement of copyrights. (See also infra note 31).

18 Firstly, patents are disclosed to the public and include the names of the inventors. Secondly, inventors (patent holders) may publish, in the scientific and technical literature the invention or technology embodied in the patent. In both ways the inventor(s) [creator(s)] will gain recognition and dignity without the protection of a moral right.

19 The authors designate this phenomenon as "IP inefficiency"

Indubitably, the conflict between patent and anti-trust policies reveals the inherent contradiction among the private and the public interests. Nonetheless, patent law should offer a balance between the freedom to use existing ideas and the incentive to innovate and create new ones.

In economic terms, the excludability right inherent in patents is generally conceived as a necessary mechanism to ensure innovation, urge further research and facilitate efficient market transactions with patent rights, as well as other intellectual property rights, see also (Landes & Posner, 2003). It is therefore argued that absent of exclusion rights, an inventor may bear all the costs of the creation of a commercially valuable invention, or other creative outcome (e.g., music) while everyone has an incentive to free ride, exploit and benefit from this innovation, at no cost and with no strings attached.

Apparently, there is a consensus in the literature of economic analysis of intellectual property rights that they enable owners to gain return on their investment made in creating, inventing and developing new and improved products and technologies. Intellectual property in all forms is in fact considered one of the major drivers of innovation in *'knowledge-based economies'* - economies which are directly based on the production, distribution and use of knowledge (OECD, 1996). Seemingly, in absence of excludability rights knowledge-based economy growth would be attenuated[20].

The economic significance and awareness of the value of patent protection is demonstrated in the WIPO's report on 'World Intellectual Property Indicators' (WIPO, 2011). Consequently, *"patent filings worldwide have reached historically unprecedented levels. The numbers of filings at the largest patent offices were stable until the 1970s, but then saw substantial growth".* Patent subject matter has expanded over the past decades to include biotechnology, software and, in some countries, methods of doing business. Figure 1 demonstrates the increase in the number of patent applications[21] during the past twenty five years.

According to WIPO, the increase in patent applications may indicate accelerated technological progress and thereby generating economic prosperity. It may also reflect the changing nature of innovation systems (WIPO, 2011). Increased international commerce and the vital need for companies to protect their knowledge in international markets are a third important factor. The number of patents granted during same period is shown in Figure 2. I argue however that the *'Total number of patents'* does not necessarily imply on the strength of the patents (e.g., validity; firm and durable claims), their commercial value or commercial exploitation.

20 It should be noted that knowledge can be non-excludable, since once it is made public, in the absence of clearly defined and protected property rights, users cannot be prohibited from using it. Some forms of knowledge are (or can be made) excludable. For instance, it may be possible to keep new knowledge secret ('trade secret'), thereby excluding use by others. The most common way of excluding knowledge is by seeking protection through patents. Nonetheless, certain advances in basic knowledge, such as mathematical theorems, are not patentable despite their importance and their potential practical applications.

21 Defined as all unprocessed applications at any stage in the application process

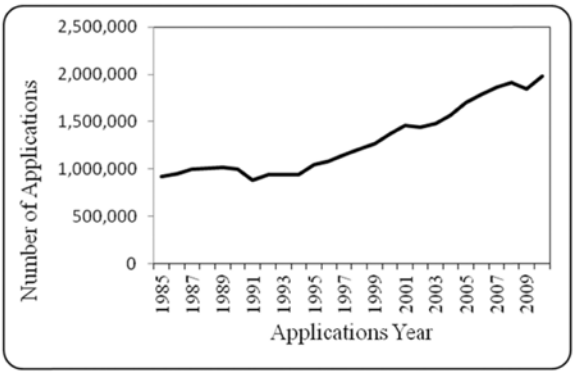

Figure 1. Trend in Total Patent Applications (1985-2010)
Source: WIPO Statistics Database, October 2011

Therefore, I propose that the latter parameters be considered and taken into account when referring to 'total number of patents' as an indicator for generating economic prosperity in knowledge based economy. As a matter of fact, it is evident that numerous patents are not and may never be used or exploited commercially. I aim to address this matter in a forthcoming paper.

Economic and Practical Analysis of Patent Right Transferability

As abovementioned, unlike other forms of property, a patent includes only the right to exclude and no other rights; whereas property rights pertaining to personal property, such as land and chattels, also secure the exclusive rights of possession, use and disposition. One of the significant rights in this bundle is the right to transfer the holder's property right to others[22]. Patents as well have the attributes of personal property. Consequently, applications for patent and patents are assignable in law. The applicant or patentee may grant and convey an exclusive (or non-exclusive) right under his or her application for patent or patents[23].

22 It should be noted that property laws impose various restrictions on this right. For example, condition to "never sell the land" imposes an invalid condition.

23 See e.g., US patent law, 35 U.S.C. 261; UK Patents Act (1977)

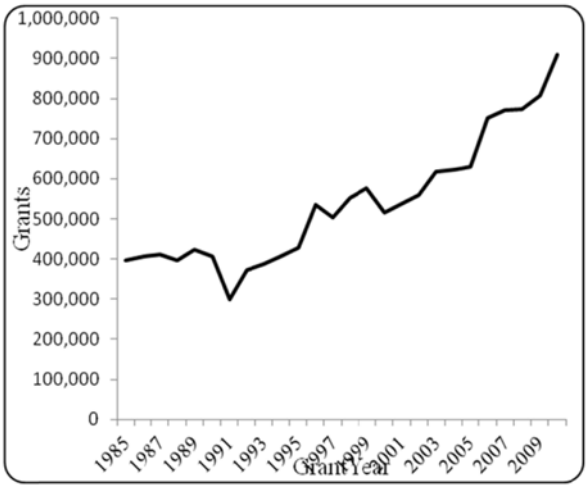

Figure 2. Trend in Total Patent Grants (1985-2010)
Source: WIPO Statistics Database, October 2011

It should be noted that granting a license *per sē* is not assigning the title to the right itself but rather granting the licensee a permission to use the invention, which is interpreted as a contractual commitment ('covenant') not to sue for an alleged infringement[24]. Hence, the licensor remains the owner and holds title to the invention. The owner may however choose to assign his or her ownership entitlement to others, pursuant to certain legal procedures and deeds[25], for a fair market value.

Ownership of the patent rights presents material legal and economic implications worthy to be briefly addressed herein. It is now a common policy and practice in developed countries that employers, as well as universities, claim and retain title to inventions made by their employees, including faculty scientists, during the course of their work. This is implemented either by legislation or contractually (i.e. employment contracts). I argue in the previous paper (Levy, 2011) that a more broad strategy should be endorsed, according to which the ownership of intellectual property rights should neither depend on the source of funding nor on the nature of the employer but rather should be determined by and depend on the employer-employee labor relations in general. Such policy is implemented, for instance, in the Israel Patent Law[26] and the UK Patent Act[27].

It is evident that transfer of property, in general, is a crucial driving force from market economy perspective. Correspondingly, the ability of a society to produce and

24 The remedies which may be available to the patent owner where infringement has been established are usually provided for in the national patent law and are generally in the form of civil sanctions, including the award of damages, the grant of an injunction or any other remedy provided in the general law.

25 Assignment requires legal procedure and registration with the patent law office.

26 The Israel Patents Law (5727—1967)

27 See also The UK Patents Act (1977).

commercialize knowledge (innovation) is critical for sustained economic growth and improved quality of life. Recent policy statements from the OECD, the World Bank, and others, clearly echo that knowledge is the most important factor in economic development. The role it plays in the process of innovation and economic growth has become even more central since the emergence of the knowledge-based economies enabled, among others, by technology transfer. Evidently, the transformation of knowledge or innovation into commercial value depends primarily on its successful transfer and acquisition.

There is an apparent universal interest in commercially exploiting viable inventions. On one hand, owner of patent rights seeks to at least return his or her investment, on the other hand, potential "infringers" seek out to improve their products or develop new ones using the invention at no cost. The patent holder can exploit the invention exclusively or can transfer the technology embodied by way of granting a license to use the patented invention to others (during the life of a valid patent) in return for a share of the revenues, normally royalties. The strength of patents (i.e. legal and economical) may be critical to the holder's decision to license new technologies rather than to use them exclusively. It is argued in the literature that in facilitating technology transferability patents may be self-correcting. A stronger legal right to exclude others from using an invention generally provides a stronger economic incentive to include them through licensing, as infringement may result in costly law suits or settlements. Whereas weak patented inventions can disseminate through non-infringing imitations or through royalty based licenses offered to discourage costly imitation by competitors (Gallini, 2002). Apparently, the economic value and the strength of the protected invention determine its transferability cost.

The transfer of the intellectual property right will impose costs on both parties attempting to determine the value of its attributes, the consequences of which was discussed above. Among others, one particular concern is the *"freedom to operate"*, namely, the ability to develop, make, and market products without legal liabilities to third parties (i.e. patent holders). Consequently, it is crucial to conduct freedom to operate analyses prior to a licensing, acquisition of patents or investment transactions in technology based companies. Similarly, freedom to operate analyses should be conducted in case several potential research pathways are feasible so as to allow selection of pathway with the least dependence on third-party patents in order to avoid potential litigation, due to infringement, or pay licensing royalties.

Patents enable companies to maintain and defend a market advantage[28]. Many companies, particularly the large ones, have a patent strategy aimed at protecting the proprietary technology thus giving their products an advantage over competing

28 It should be noted that companies' intellectual property management can be divided into two areas. The first concerns internal management (disclosures, patent applications, maintenance, etc.). The second concerns external management, primarily how a company interacts with other companies' intellectual property rights and vice versa; as well as monitoring possible infringements and initiate litigation process.

products. Moreover, companies' research and development (R&D) strategy is often driven by the potential strength of their patents. Indubitably, nowadays companies are urged to develop, or acquire, a sustained patent portfolio.

A recent vivid example that demonstrates the materialization of such strategy is the recent transaction in which Microsoft acquired from AOL more than 800 patents for $1.056 billion in cash[29]. This remarkable transaction reflects the crucial role that patents are increasingly playing in the business of the world's leading technology companies.

It should be pointed out that different industries vary greatly in how they approach innovation and the importance of innovation to sustained growth. The pharmaceutical industry exemplifies this paradigm. In this industry, a patent represents only the beginning of a long and particularly costly process of developing a marketable medicine. It is a common knowledge that the development of new drugs (and medical innovations in general) requires massive long term investments in R&D, expertise in pharmaceuticals development, obtaining regulatory approval, production and marketing capacities. On average, developing an innovative new drug takes about 12 years. A recent estimate of the average cost of developing an innovative new drug is over $800 million, including expenditures on failed projects and the value of forgone alternative investments (DiMasi, Hansen, & Grabowski, 2003). Large pharmaceutical companies find viable innovation to be much more difficult to accomplish internally (Christensen, 1997). The challenges, including, among others, lack of in house basic research set-up and activities, encourage large pharmaceutical firms to pursue collaborative alliances. Majority of these alliances materialize through licensing transactions with university scientists and small spin-off companies[30]. Some remarkable licensing instances of basic research in the medical field from academia in Israel to industry are shown in Table 1. Pharmaceutical executives seem to recognize that collaborative arrangements provide a vital mechanism enabling to expand product pipeline. With fewer new drugs coming to market and proprietary drugs losing their market protection from generics, big companies switched to mergers and acquisitions for continued growth, *inter alia*, by acquiring patent rights to proprietary drugs[31].

29 See AOL press release - http://corp.aol.com/2012/04/09/aol-and-microsoft-announce-1-056-billion-patent-deal/

30 For further discussion on the significance of technology transfer from university to industry see e.g., (Levy, 2011)

31 Pharmaceutical company mergers and acquisitions reached $690 billion over the last decade. For instance, GlaxoWellcome's 2000 acquisition of SmithKline Beecham was valued at $74 billion. Other large deals included Sanofi-Synthelabo's $65.5 billion acquisition of Aventis in 2004; Merck & Co.'s acquisition of Schering-Plough for $41.1 billion in 2009; and Bayer AG's $21.5 billion acquisition of Schering AG in 2006. I should point out, however, that while mergers and acquisition among pharmaceutical companies seems to be beneficial to both parties, the outcome of mergers and acquisition in the pharmaceutical-biotechnology industry seems to have failed. It is estimated that trillion dollars in the market value were erased in the past decade. This fact can be partially explained by failure of clinical trials and discontinuing R&D projects.

Table 1. List of Licensed innovative Drugs from Universities in Israel

Product	Indication	Licensee	Sales in 2011 (in millions)	Licensor
Copaxone	Multiple Sclerosis	Teva	$3,570	Weizmann Institute (WI)
Rebif	Multiple Sclerosis	Merck-Serono	€1,691	WI
Exelon	Alzheimer	Novartis	$1,067	Hebrew University (HU)
Doxil[a]/Caelyx	Cancer	Schering-Plough	$320 [b]	HU and Hadassah Hospital
Aziltec	Parkinson	Teva	$290	Technion Medical School
Erbitux	Cancer	Merck-Serono	€855	WI

Sources: Companies' Annual Reports 2011

[a] Sold by Johnson & Johnson (through its acquisition of Alza) in the United States and Schering Plough (under the trade name Caelyx) internationally. Source: http://www.zoominfo.com/#!search/profile/person?personId=1059435901&targetid=profile.

[b] In 2010, Source: http://www.evaluatepharma.com/Universal/View.aspx?type=Entity&entityType=Product&id=12704&lType=modData&componentID=1002.

In many industries companies license a product patent(s) for productive efficiency reasons, particularly, to achieve lowest manufacturing and distribution costs and yet gain from permitted production and sales by third parties. It is likely that a patent holder, which manufactures and sells a protected product, may not be situated to supply the market demand or to export to other territories due to shortage of production facilities, distribution setup or adequate finance to expand its operation. It is therefore a common practice that large established companies license out the production and sales of their patented product to third parties for generating more revenues, sometimes even to competitors[32]. For instance, in the computer industry IBM's know-how along with intellectual property assets reaches into nearly every industry and every discipline of science and technology. IBM's revenues from intellectual property and custom development income reached over $1.1 billion[33] in 2011, accounting for circa 7 percent of IBM's net profit. The noteworthy feature is that often large companies license their protected technology and knowhow to potentially competitors.

A well-known illustrative and worth noting example of licensing to potential competitors is the case of VCR (Video Cassette Recorder) technology[34]. In 1975 Sony introduced the Betamax, a proprietary technology, which represented a breakthrough on the VCR market. A year later, a competing (apparently lesser than Betamax)

32 Interestingly, an OECD report revealing statistical data shows that licensing markets (related to Europe and Japan) are less developed than they could be, in view of the willingness of patent holding companies to license more of their portfolio (Zuniga & Guellec, 2009): "About 20% of European companies and 27% of Japanese companies holding patents license out at least one of their patents to an unaffiliated partner. The relationship between size and probability to license out among patent holding companies is U-shaped: the smallest ones and the largest ones are more often involved in licensing out than medium-sized ones. The highest proportion of firms license-out in Europe is found in the UK, followed by Nordic countries. Cross-licensing out is the second motive for licensing out, both in Europe and in Japan: that shows a role played by patents in technology exchanges between companies".

33 That includes $309 million from sales and other transfers of intellectual property; $211 million from Licensing/royalty-based fees and Custom development income contributed $588 million, in total $1,108 million. Source: IBM 2011 Annual Report.

34 See e.g., http://www.videointerchange.com/video-history.htm#BetaMax; http://www.gaoshan.de/university/presentations/VCR-Battle-handout.pdf.

technology, VHS (Video Home System) was introduced by JVC (Victor Company of Japan, Ltd.). The strategy of JVC and Matsushita Electric International (Panasonic) was aimed at creating an alignment of producers and gaining market share. The two companies agreed to ship original equipment manufacturer (OEM) VCRs to their licensees and then to further development of the VHS system. This helped the two companies to gather numerous partner companies around them, whereas Sony's approach to exclusively use its technology was seen by most as uncooperative. The outcome was that in 1978 all major European producers adopt VHS standard and in 1984 US partner Zenith abandons the Betamax format. Betamax format has practically become obsolete. Albeit this case undoubtedly reveals a remarkable business strategy, it similarly demonstrates the economic impact and significant contribution of technology transfer or from legal perspectives transferability of intellectual property rights in general, and to competitors, in particular.

An additional notable approach is the *'cross-licensing'*. Accordingly, two (or more) companies grant each other cross-licenses to all technology developed by either party during a defined period with corresponding payments being made to cover any deficit in the value of technology licensed by one side or the other. Consequently, cross-licensing allows freedom to operate for each party[35]. This approach, for instance, is common among Japanese electronics companies.

One noteworthy example of an open cross-licensing transaction illustrates the transfer of technology from Japan to Asia. In the early nineties Samsung Electronics and Fujitsu entered a broad cross-licensing agreement that allowed each access to the other's microchip technologies patented in the US, Japan and Europe. Under the agreement Samsung paid Fujitsu ¥4 billion to compensate for Fujitsu's technological edge. This was some 25 percent of Samsung's 1991 pre-tax profits and the first time that Fujitsu had received royalties from a Korean firm in a cross-licensing agreement (Miyake, Yoshikawa, & Inoue, 1992). It can be safely stated that cross-licenses may be especially useful in industries, such as the semiconductor and computer industries that are characterized by large numbers of overlapping patent rights

An additional related licensing arrangement is known as *'patent pools'*, which generally are created when a group of patent holders each decides to license its respective patents to each other and to third parties collectively. In many industries, the patent rights necessary to commercialize a product are often controlled by several rights holders. This can increase the transaction costs of negotiating multiple licenses and greater cumulative royalty payments. They are often formed when multiple patented technologies are needed to produce a standardized product or to solve the blocking patents situation. Pools composed only of complementary patents tend to

35 I should point out that one may argue that in certain legal jurisdiction cross-licenses provisions may allegedly violate anti--trust laws. My surmise however, that such claim is not self-evident. In 1995, the U.S. Department of Justice and U.S. Federal Trade Commission issued its "Antitrust Guidelines for the Licensing of Intellectual Property," which explicitly noted, cross--licensing and pooling arrangements may provide pro-competitive benefits (http://www.usdoj.gov/atr/public/guidelines/ipguide.htm). However, provisions in portfolio cross licenses that may facilitate price fixing, for example, can raise antitrust concerns.

increase efficiencies and lower prices to consumers. However, it is argued that pools composed of pure substitute patents, are more likely to harm social welfare than are pools of complementary patents (i.e., that do not compete with each other). Seemingly, the current form of patent pools that have been approved by the U.S. Department of Justice (see Chapter 3: Antitrust analysis of portfolio cross-licensing agreements and patent pools in guideline (2007)) have been highly beneficial to the public, with no apparent anticompetitive effects[36]. The Japanese Guidelines for the 'Use of Intellectual Property under the Antimonopoly Act' provides an additional supportive case[37]. A representative example is the MPEG-2 patent pool, where in spite of the patent pool competition did not cease, to the contrary, companies have and continue to develop new digital video standards[38] (for further reading on patent pools efficiency, see e.g., (Lerner & Tirol, 2004).

In summary, patents enable companies to maintain and defend a market advantage over competitors. In many industries companies license a product patent(s) for productive efficiency reason, particularly, to achieve lowest manufacturing and distribution costs and yet gain from permitted production and sales by third parties. However, when the patent rights necessary to commercialize a product are controlled by several holders of rights they will often prefer to cooperate and share patented knowledge through cross-licensing and patent pools. The various licensing approaches have been profitable not only to the companies but also have been highly beneficial to the public.

Conclusions

Unlike tangible property right, which includes the right to exclude as well as a bundle of other rights, intangible property or intellectual property right includes only the right to exclude. The exclusiveness nature of patent rights is conceived to be essential and instrumental for efficient exchange transactions. From economic perspective, the right to exclude confers (quasi) monopoly rights to the owner to prevent others from commercially exploiting the protected knowledge (invention). I agree with the conception that the (quasi) monopoly right purpose is to ensure further innovation and knowledge which are critical for sustained economic growth and improved quality of life and welfare.

The patentee (or patent applicant) may grant to others, by way of a licensing arrangement, a right under his or her patent application(s) or patent(s) to use make and sell a protected product (invention). In economics terms, the developer of knowledge or technological innovation and owner of intellectual property rights avails it to an appropriate business (strategic) partner for more efficient commercial exploitation.

36 See e.g., James J. Kulbaski, Comments on Patent Pools and Standards for Federal Trade Commission Hearings Regarding Competition & Intellectual Property (Apr. 17, 2002 Hearing R.) at, http://www.ftc.gov/opp/intellect/020417jamesjkulbaski.pdf.

37 http://www.jftc.go.jp/en/legislation_guidelines/ama/pdf/Patent_Pool.pdf.

38 such as MPEG-4 and MPEG-7 that are advantageous over MPEG-2.

It should be noted that universities have become more important players in knowledge-based economies and scientists, researchers and engineers have played a critical role in driving technological progress and innovation. It is evident that for universities technology transfer by way of licensing out[39] can successfully and effectively bring their innovation through to the market place.

Nowadays companies are urged to develop, or acquire, a sustained patent portfolio. In industries where blocking patents exist, such as the semiconductors, companies exchange and use knowledge and technology among themselves via two efficient instruments, cross-licensing and patent pools. These patent rights transferability approaches have been proven to be efficient and profitable to the companies as well as beneficial to the welfare of society.

To conclude, the role technology transfer plays in the process of innovation and economic growth has become more central since the emergence of the so-called knowledge-based economies. Moreover, the transformation of patented knowledge and innovation into commercial value depends primarily on strong intellectual property rights and efficient transfer and acquisition.

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Abstract (in Polish)

Przekształcenie innowacji w wartość handlową zależy przede wszystkim od odpowiedniej ochrony własności intelektualnej poprzez patenty oraz wydajnej organizacji transferu chronionej wiedzy. Kluczową cechą patentów, z perspektywy ekonomicznej jest to, że obejmują one nową wiedzę oraz przyznają prawa wyłączności właścicielowi. Wyłączność praw patentowych jest zazwyczaj postrzegana jako konieczny mechanizm dla zapewnienia dalszej innowacyjności, stymulowania zaawansowanych badań oraz ułatwiania wydajnych transakcji rynkowych dotyczących praw patentowych. Właściciel patentu może przekazać objętą patentem technologię poprzez przyznawanie zainteresowanym licencji z prawem wykorzystania opatentowanego wynalazku w zamian za odpowiednią gratyfikację. Transfer praw patentowych jest postrzegany jako wydajne i rentowne przedsięwzięcie zarówno dla przemysłu jak sytuacji materialnej społeczeństwa. Przedmiotem dyskusji są perspektywy ekonomiczne i praktyczne tranferu i komercjalizacji praw patentowych.

Słowa kluczowe: blokowanie patentów, licencje, wykluczenia prawne, prawa własności intelektualnej, innowacje, wiedza, licencjonowanie, patenty, transfer technologii, przeniesienia.

The Role of the Internet in Overcoming Information Barriers: Implications for Exporting SMEs of the East African Community

Neema Mori*, Gibson Munisi*

Abstract

Small and medium-sized enterprises play a significant role in the East African Community, contributing highly to the national income and employing a significant number of people. Exportation provides a great opportunity for these enterprises to expand their businesses and improve their performance. However, they encounter a number of information-related barriers before and during exportation. Based on literature, this paper identifies these barriers and discusses how the internet could be used to reduce them. Based on the internet, international business and small business literature, the paper provides propositions and develops a model that will be useful for future studies in this area.

Keywords: SMEs; Information barriers; Internet; Exportation; East African Community.

Introduction

In the last few years, the use of the Internet in the East African community (EAC) has grown thanks to the introduction of international fibre bandwidth in these countries in 2010. This has facilitated high access to the Internet as it has become relative cheaper and more reliable (Lange, 2011). Also, the use of mobile telecommunications has increased access to the Internet for many people in the region, not only in big cities but also in remote areas where a large proportion of the population still lives. This arrival of bandwidth has been received with great optimism by various stakeholders in the EAC. As part of the on-going process, it is believed that proper use of the Internet could have positive effect on the lives of many East Africans through enhanced communication and information technologies.

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One important business area in which the EAC countries have started benefiting from Internet access is exportation (Boateng, Hinson, Heeks, & Molla, 2008). Most businesses in the EAC are small and medium-sized enterprises (SMEs). SMEs play a significant role in the world's economy (Anderson, 2011; Dietl, 2005; Kyereboah-Coleman & Amidu, 2008). Grossman and Helpman (1989) further show that SMEs are able to grow because of improvements in technology, which enable them to introduce new products and services. Because of their growth, SMEs are able to make a major contribution to the national income and employ a significant number of people. Furthermore, SMEs are major players in exportation, as they are often involved in the production and export of goods and services (Knight & Kim, 2009).

However, SMEs from the EAC are not performing well in exportation because of the various export barriers they face (Husein, 2009; Milanzi, 2012). Because of this, EAC countries' involvement in exportation is low compared with other regions and continents and, as a result, they are lagging behind in terms of economic and social development (Asiedu, 2004; Bakunda, 2003). For those that are participating in exporting, their performance is not as good as expected. One of the barriers to exporting facing these SMEs is their poor access to and knowledge of information and communications technologies (Ernst & Young, 2009; Anderson, 2011).

The use of the Internet as an important communication tool could help prevent SMEs from being left behind (IFC, 2012). Together with the business experience SMEs already possess, they could make use of the Internet to facilitate their operations, particularly for accessing international markets. In the light of this, the objectives of this paper are to (1) identify and discuss the information-related barriers faced by exporting (and non-exporting) SMEs in the EAC; (2) discuss the role of the Internet in helping to reduce these barriers and enhance SMEs' export performance.

A full evaluation of the implications of Internet use for SMEs' export performance may require a thorough empirical analysis. This paper therefore provides a foundation for such analysis by providing a descriptive analysis, propositions and a model that can be used in future research to empirically explain the relationship between the information-related barriers facing SMEs, the use of the Internet, and SMEs' export performance.

The rest of this paper is organized as follows. The next section presents the methodology used in this study. This is followed by a background section discussing the Internet and exportation by SMEs. The EAC is introduced after this. The following section describes the role of the Internet as regards SMEs and develops propositions and a model. The final section presents the conclusion, theoretical and practical implications and areas for future research.

Methodology

This paper uses two methods, literature review and secondary data analysis. The review of literature methodology, as argued by Boateng et al (2008), enables researchers to identify critical knowledge gaps, to alert other researchers to opportunities for further

contributions and to chart a course for future research. We therefore start by reviewing the global literature on the Internet and exportation. This is followed by a literature review on SME exportation in terms of the opportunities and challenges faced when seeking to export. Since the study focuses on discussing the implications for the EAC, a related literature search was conducted, followed by the gathering of secondary data, both looking at the background of the community, SMEs' exports from it and the information-related barriers facing SMEs there. The literature review and secondary data analysis (provided in tables 1, 2 and 3) led to the development of propositions and a conceptual model that suggests that the Internet has a direct and moderating effect on overcoming information barriers and improving SMEs' export performance.

The Internet and SME Exportation

The Internet: Meaning and business use

The Internet is regarded as one of the extensive forms of communicating, and the one with the great business potential, worldwide (Shabazz, 2000). Obra, Cámara, & Meléndez (2002) describe the Internet as an international computing system that enables firms to exchange information internally and communicate externally with other organizations. Hamill (1997a) lists users of the Internet as including individuals, companies, governments, universities, research establishments and many others. As a component of information technology (IT), the Internet gives users the ability to exchange, integrate and manipulate data (text, video graphics, and audio) over long distances at high speed (Shabazz, 2000). Similar to Obra et al. (2002), this study defines internet access as having an Internet Service Provider that will enable the user to visit any website, to obtain information from that website, and to send and receive emails and transfer files.

The Internet has many uses and in terms of business usage, as it has been argued that it has been and will continue to be the arena for exchange between buyers and sellers in the future (Abratt & Silva, 2002). The literature suggests that the Internet is used by businesses in a number of ways. First, it is used for internal and external communication via e-mail. Second, it is used in corporate logistics; for example, multi-user dialogue can be used to achieve "real time" communication across distances. Third, it can provide more rapid access to international markets. Fourth, firms can use it to achieve a competitive advantage, for example, by erecting barriers to entry. Other uses mentioned in the literature include online support for inter-firm collaboration, especially in R&D, as a tool for searching for and retrieving information, for creating websites for marketing and sales promotion purposes, and for transmitting any type of data (Hamill, 1997a; Grossman & Helpman, 1989).

These benefits from using the Internet could be far-reaching for SMEs and, when used in conjunction with other resources (such as better managerial support and flexibility), could provide them with a major competitive advantage. Obra et al. (2002) further contend that the Internet can alter an SME's cost structure as it affects the elements needed to manage information, hence enabling their active participation in exportation.

SME Exportation

Exporting has traditionally been regarded as the first step in entering international markets (internationalization) and it serves as a platform for future international expansion (Owusu & Habiyakare, 2011). It is considered a popular strategy for SMEs because it does not require significant resources (Hornby, Goulding, & Poon, 2002) or a high level of market knowledge or experience (Johanson & Vahlne, 2009). Internationalization through exporting is also considered a useful way for SMEs to increase their growth. According to the traditional stage theory of the firm (Johanson & Wiedersheim-Paul, 1975), internationalization is achieved through a developmental and sequential process with the following steps: (i) no regular export activities, (ii) exporting *via* independent agents, (iii) establishing sales subsidiaries, and (iv) starting production in a foreign country.

Similarly, Bakunda (2003), focusing on exportation by African firms, identifies four stages. He argues that SMEs start out as family-owned businesses, serving the domestic market. Through this process, SMEs are able to make contacts and form networks[40]. The second stage involves the firms setting up production facilities locally, using imported technology and raw materials, and producing for the local market. In the third stage, the SMEs start to export to neighbouring markets. Finally, they export to overseas markets that are further afield. Bakunda further contends that moving between these stages is associated with three aspects: the presence of networks, international exposure and an understanding of markets.

These aspects are also considered in the revised internationalization process proposed by Johanson & Vahlne (2009). They argue that, nowadays, the business environment is a web of relationships. Therefore, through interactions and networks, businesses can create knowledge, and channel valuable information and resources, which they can use to identify foreign market opportunities. In other words, firms no longer need to go through each individual stage in order to become international. Networking and interactions are thus important for SMEs in terms of operating in international markets, especially exportation (Zhou, Wu, & Luo, 2007).

Furthermore, the literature has shown that there are SMEs that start exportation from their inception or after a few years after inception (Zhou et al., 2007). This is argued to be a result of fast-changing economic, technological, social and networking conditions (Johanson & Vahlne, 2009). One of the frequent motives for exporting is to gain access to new and larger markets in order to achieve growth and, as a result, remain competitive and perform better (Masum & Fernandez, 2008).

However despite SMEs' willingness and potential for exportation, there are complexities involved that are associated with the distance, risks and other barriers

40 We define networks as a set of long-term contacts between people or organizations in order to get information and build resources. They are further made up of people, who are united by work, friendship, influence or communication. These networks can further be categorized as business and/or social networks. A business network is a set of two or more connected business relationships, in which each exchange is between businesses that are conceptualized as collective actors, while social networks refer to a web of personal connections and relationships for the purpose of securing favours for personal and/or firms' advantage (Anderson, Hakansson, & Johanson, 1994).

(Tesfom, Lutz, & Ghauri, 2006). Due to these barriers, some SMEs decide not to participate in exportation, which puts them at a disadvantage compared to those that engage fully in exportation (Anderson, 2011; Leonidou, 2004).

In this regard, the Internet could be helpful in reducing some of the barriers that are encountered – specifically, the information-related barriers –thereby enabling SMEs to capture the benefits of exportation (Hornby et al., 2002). It could help exporting SMEs to leapfrog the conventional stages of internationalization (Bennett, 1998) and some of the stages of exportation listed by Bakunda (2003) by removing many if not all of the geographical and informational barriers and permitting virtual branches to be established instantly, throughout the world, granting SMEs direct and immediate foreign market entry (Bennett, 1998).

The aim of this paper is therefore to look at how the Internet could specifically reduce the information-related barriers faced by SMEs exporting from the East African region. The paper focuses on this region because of the contextual similarities of the countries, all of which are members of the EAC. As Hornby, Goulding & Poon, (2002) note, SMEs' export barriers are shaped by the contextual background of the firms, which is why this study focuses on the EAC and draws conclusions based on the information-related barriers that are faced by SMEs in that community. To provide the necessary background, the next section examines the EAC.

The East African Community

Background

The EAC is the regional intergovernmental organization of the Republic of Kenya, Uganda, the United Republic of Tanzania, the Republic of Rwanda and the Republic of Burundi[41]. The agreement establishing the EAC was signed in November 1999 and came into force in July 2000. The community aims at widening and deepening cooperation among the partner states in, among others, political, economic and social fields, for mutual benefit. To this end, the EAC countries established a Customs Union in 2005 and a Common Market in 2010. The community is currently working on establishing a monetary union and, ultimately, aims to become a political federation of East African countries.

The five partner countries had a combined population of more than 130 million people as of 2010, a land area of 1.82 million square kilometres and a combined gross domestic product of $74.5 billion as of 2009 (EAC, 2011b). These features give the EAC great strategic and geopolitical significance and the potential for a renewed and reinvigorated region. Furthermore, the community has vast potential in terms of mineral, water, energy and wildlife resources. It is also currently engaged in agricultural, livestock, industrial and tourism development (EAC, 2011a). The people of this community have a common history, a common language (Kiswahili), and a shared culture and infrastructure

41 Borrowed from the EAC website: http://www.eac.int/about-eac.html.

(Ernst & Young, 2009). Table 1 shows selected basic information on the EAC partner countries.

Table 1. EAC Countries: Basic Information

Partner member	Land area in 000s sq. kms.	Population in millions (2010)	Real GDP in million USD (2010)	GDP per capita USD (2010)
Burundi	25.0	8.4	1,499.1	173.0
Kenya	580.7	38.6	18,543.7	833.4
Rwanda	24.2	10.4	4,032.6	540.0
Tanzania	886.3	43.9	11,941.1	546.7
Uganda	199.8	31.8	9,538.9	525.9
East Africa	1716.0	133.1	45,555.4	685.0

Overall, this table shows that the EAC has a large potential market in terms of suppliers and customers of various products, and therefore has great potential for accelerating growth and becoming competitive in the global market. This is further shown in the EAC development strategy for the next decade (2011–2020), which is focused on improving global competitiveness so as to provide faster and sustainable economic growth and move closer to the status of a newly industrialized region (EAC, 2011a). The aim is to achieve this through, among other things, the region's active support of its SMEs and improvements in global communications/information technology.

Internet use in the EAC

In 2010, the region was connected by a second fibre optic cable linking East Africa to the rest of the world, and specifically to Europe. The cable is known as the East African submarine cable system. The cable led to better Internet access and improved connections in the region. The EAC (2011a) report argues that access to and use of information and communications technology (ICT), including the Internet, is essential for the development of the EAC, both from an economic and social viewpoint. The report further shows that ICT is growing at a fast rate in the region, although the statistical indicators used to measure this development may not be completely reliable.

Information from the internetworldstats website[42] further shows that growth in East Africa's internet and broadband sector has accelerated in recent years due to improvements in infrastructure, the arrival of wireless access technologies and lower tariffs. Broadband is rapidly replacing dial-up as the preferred access method in the region. The use of social media such as Facebook, Skype, LinkedIn and Twitter is also growing. The website, for example, shows that three EAC partner states (Kenya, Tanzania and Uganda) are among the top ten African countries in terms of number of Internet users. Table 2 shows that in these three countries internet users make up

42 http://www.internetworldstats.com/stats1.htm.

more than 10% of the total population. This shows the great potential of the Internet for many endeavours, including participation in international markets through exportation.

Table 2. Internet users (million people)

Country	Year 2000	Year 2011	% of population	% of population (Africa)
Burundi	3,000	176,040	1.7 %	0.1 %
Kenya	200,000	10,492,785	25.5 %	7.5 %
Rwanda	5,000	818,048	7.2 %	0.6 %
Tanzania	115,000	4,932,535	11.5 %	3.5 %
Uganda	40,000	4,178,085	12.1 %	3.0 %

Source: Internetworldstats.com. Accessed 20th April, 2012.

Exportation from the EAC

The EAC encourages exports by SMEs and large enterprises. Similar to other African economies, the governments of the partner states have adopted export promotion strategies (Anderson, 2011; Bakunda, 2003). The establishment of the customs union has catalyzed the expansion of trade. Exports between countries within the community (intra-EAC trade) grew by 40% between 2005 and 2009. For example, Uganda's exports to Kenya increased more than tenfold, while Tanzania's exports to Kenya over the same period nearly tripled (EAC, 2011b). This increased trade and investment among the EAC partner states has broadened the prospects for economic growth and is also expected to extend to other countries globally. Table 3 shows the trend in exports to other parts of the world over the period 2006-2010.

Table 3. Export trends in the EAC (million USD)

Country/Year	2006	2007	2008	2009	2010
Burundi	15.59	10.59	10.85	18.35	117.34
Tanzania	2,000.12	2,007.00	3,119.30	2,982.45	3,976.79
Uganda	962.19	1,336.67	1,724.30	1,567.61	1,618.60
Kenya	3,481.19	4,080.02	5,054.16	4,462.48	5,180.70
Rwanda	143.50	183.98	399.99	211.86	237.80

Source: EAC (2011b).

SMEs contribute greatly to exports in this region. Reflecting this, the current EAC development strategy for 2011-2016 indicates that the SME sector forms the bulk of the industrial sector (by number of firms), and contributes more than 60 percent of employment in the region. The strategy indicates further that this sector has the potential to address the development needs of the region, through poverty reduction, technological innovation, economic linkages and the reduction of disparities in regional development, if well supported and brought into the mainstream of the formal economy (EAC, 2011a). As a result, one of the current priorities for the EAC

is to facilitate the development and growth of SMEs, including helping them to excel in regional and international markets through exportation (Ernst & Young, 2009; EAC, 2011a). The EAC strategy also mentions that SMEs in the region are currently expanding their businesses to partner states and internationally.

However, SMEs face a number of barriers that hinder them from participating fully in exportation. Delloitte (no year) lists various barriers faced by SMEs in the EAC, including (but not restricted to) the weak labour market, lack of access to finance, international competition, weak management skills, the lack of international experience and poor information technology. Hussein (2009) mentions that similar barriers are faced by Tanzanian exporters. The focus of this paper, however, is on information-related barriers, and the next section describes the types of barriers caused by poor or missing information.

Information-Related Barriers Faced by Exporting SMEs

Various information-related barriers are faced by SMEs globally. Many of these are also faced by SMEs in the EAC. The following barriers are drawn from the literature, including empirical studies carried out in the EAC:

Lack of information to locate and analyse foreign markets: Many SMEs lack adequate information about foreign markets. Anderson (2011), for example, conducted a study on SME internationalization in Tanzania and found that the export performance of 35% of SMEs may be affected by this barrier.

Inability to contact overseas customers: The export promotion strategies adopted in many African countries, including those in the EAC, have enabled some SMEs to make contacts in overseas markets (Anderson, 2011; Bakunda, 2003). However, the challenge is the reliability of accessing such contacts.

Inability to identify foreign business opportunities: This is a key aspect of SMEs' export performance. SMEs need to know where they might find business opportunities and where there might be a market for certain products. Anderson (2011) shows that 40% of exporters obtained their markets through participation in trade fairs. It seems that many exporting SMEs are not able to identify markets, either through trade fairs or any other means. In addition, there seems to be an overall lack of knowledge among SMEs as to how and where they might search for business opportunities (Tesfom et al., 2006).

Distribution channels: The barriers faced by EAC SMEs in this area include gaining access to export distribution channels, the complexity of local and foreign distribution channels, control by foreign middlemen, and long delivery times (Mori, 2010). All of these issues are related to inadequate information. If an SME has more information about the choice of distribution channels available, it will be better able to select the most appropriate one for its needs. Information also gives SMEs more power to deal with middlemen.

Lack of product promotion: The ability to excel at exporting requires that products are promoted effectively. The EAC countries have adopted promotion campaigns and

export development strategies to boost their export performance. Advertising is one of the most widely used means of communication and promotion in international markets (Darley, 2002). However, SMEs may find it difficult to produce effective advertisements for a number of reasons, including ignorance about what is required, the inability to promote their product to the target audience, and, as a result, inappropriate content in the advertising message. Exacerbating this, the promotion campaigns in the EAC are currently mainly focused on trade fair participation, which is insufficient for improving SMEs' export performance (Mori, 2010).

In summary, barriers associated with communication and access to information seems to be the concern of many of the SMEs engaged in exporting (Delloitte, no year; Tesfom et al., 2006). Clearly these problems need to be tackled. This paper contributes to this objective by analysing how use of the Internet could help SMEs to reduce or eliminate these problems and become more successful in international markets. By taking into account the effects of the internet on exportation, the next section discusses how it could help SMEs to overcome some of the information-related barriers identified in this section. Propositions are stated and a model is presented.

The Role Of The Internet For Exporting SMEs In The EAC

The Internet provides organizations, including SMEs, with new ways of conducting business by exchanging information and business ideas. This section argues that the opportunities provided by the internet would enable SMEs to overcome information-related barriers.

The Internet has the ability to transform an organization's operations if used properly. For this reason, many firms use the Tnternet as a major strategic informational tool. They also use the Internet to gain an edge in an increasingly competitive business environment, both domestically and internationally (Anderson, 2011; Dholakia & Kshetri, 2004).

International market costs

Internet technology enables SMEs to improve the efficiency of their performance and develop new ways of coordinating their activities in the international context (Loane, 2005). It offers SMEs an important resource that can be used to carry out export activities cheaply. SMEs which are using the Internet can quickly gain global recognition via a website and email, without too much difficulty. In his study, Bennett (1998) observes that the Internet is a valuable tool for generating sales leads, helping SMEs to sell their products in remote countries, to penetrate unfamiliar markets and to create international awareness. These benefits can be achieved at little cost.

In addition, marketing costs, such as advertising costs, can be significantly reduced as the internet makes it possible to reach a global audience cheaply (Hamill, 1997b). Also, SMEs offering specialized products for a niche market may be able to cheaply find the many customers needed to succeed internationally through the worldwide reach

of the internet (Hamill, 1997b). Based on the above arguments, we make the following proposition:

P*roposition 1: The use of the Internet enables SMEs to reduce the costs of accessing international markets.*

Communication with customers

One of barriers encountered by SMEs is the inability to communicate with overseas customers (Fillis, 2002; Husein, 2009; Leonidou, 2004). The main reasons for this are the large physical and psychological distances involved in reaching international markets and the poor communications infrastructure in many countries (Leonidou, 2004). SMEs can use the internet as a communications tool to overcome this problem if other countries with which they are communicating also have good communications infrastructure. The Internet acts as a global channel through which both existing and potential customers can be targeted. SMEs can use it to publicize their commercial offerings (Melewar & Smith, 2003).

In addition, according to Poon and Swatman (1999), the most useful function of the Internet is the use of e-mail to conduct business communications. Qualman (2009) also notes that the use of social media such as Twitter and Facebook not only enables social interaction but also the building of business networks. The Internet offers something that telephone and fax services cannot, namely, asynchronous communication, which overcomes time and geographic limitations, and electronic document transmission (Poon & Swatman, 1999).

Thus, SMEs could use the Internet as a communications tool to facilitate interaction with overseas customers. This leads to the following proposition:

Proposition 2: The Internet facilitates SMEs' communication with overseas customers.

Distribution channel's effectiveness and efficiency

Having an effective distribution channel is one of the most important factors for ensuring that the export business is successful. In many trading activities, the distributors are the key link between the manufacturer and the customer (Tesfom et al., 2006; Wilkinson & Brouthers, 2006). However, the ability of SMEs to access appropriate distribution channels can be hampered by a number of factors, such as competition from large firms that already control distribution, physically long channels that drive up the costs to a level that SMEs cannot afford, and a system in which the distributors have an excessive amount of control and SMEs have weak bargaining power (Wilkinson & Brouthers, 2006).

The Internet helps SMEs to overcome these problems because they could use it to eliminate redundant processes and establish direct links with customers. By connecting end-users and producers directly, the Internet reduces the importance of traditional intermediaries in international markets, thus speeding up SMEs' entry into the export business (Hamill, 1997b). Thus, the following proposition is posited.

Proposition 3: The use of the Internet reduces SMEs' distribution channel barriers.

Selling to foreign market customers

The Internet enables SMEs from the EAC to instantaneously position themselves in many foreign markets at the same time (Bennett, 1998). As a result, customers would have the opportunity to search and buy from any place in the world and at any particular time via firms' websites. Thus, use of the Internet would enable SMEs to overcome foreign customers' accessibility problems. For example, information could be accessed via the web about small hotels and tour operators located in remote areas of Tanzania and Burundi. Websites provide information about the services a firm is offering customers located anywhere in the world, which could be accessed at any time. As a result, SMEs are able to access international markets directly via their websites, and export the goods or services demanded by foreign market customers. This leads to the following proposition.

Proposition 4: The Internet enables SMEs to market and sell their products to foreign customers.

Risk assessment and the identification of business opportunities

One of the main barriers hindering SMEs from exportation is that it is difficult for them to identify foreign business opportunities (Leonidou, 2004). This has been highlighted as a problem for SMEs from the EAC (EAC, 2011a). The internet provides the opportunity for firms to identify, access and utilize new business opportunities, for example, by facilitating the search for and retrieval of information (Peterson, Balasubramanian, & Bronnenberg, 1997). For example, firms can find business partners on the web, via networks of suppliers and customers of various goods and services set up specifically to provide opportunities for trade. There are a number of websites providing this type of service (Bennett, 1998). SMEs could use these types of networks, and other opportunities offered by the Internet, to interact, form business contacts and identify foreign business opportunities.

Exportation is typically perceived as a risky undertaking for any firm regardless of size (Ghoshal, 1987; Johanson & Vahlne, 2009). According to (Ghoshal, 1987), an international firm faces many kinds of risk, some endemic to all firms and others unique to organizations operating across national boundaries. These perceived risks can often be a major hindrance to an SME aiming to export, particularly as they may lack adequate information about foreign markets that might help mitigate such risks (Johanson & Wiedersheim-Paul, 1975).

It can be costly for SMEs to access this information; as a result, they may be at a disadvantage compared to large firms with a huge amount of resources. However, if SMEs started using the internet it would alter the situation in their favour, as it would provide a vast amount of information that could be used to assess the risks associated with international business and to identify appropriate new opportunities in foreign markets. On the basis of this argument, the following proposition is suggested.

Proposition 5: The use of the Internet assists SMEs to assess the risks in international markets and to identify appropriate business opportunities.

Global marketing Promotion

By using the Internet as a communications tool, SMEs in the EAC would be able to devise suitable global marketing strategies. Having a presence on the web means that a firm is international (Yi-Long & Chun-Liang, 2006). The internet can be used as a fully-fledged global marketing communications channel, and can deliver many aspects of an organization's global marketing strategy, including branding, database building, and customer acquisition, providing customer services, forming relationships and building loyalty (Melewar & Smith, 2003).

This is particularly relevant for SMEs that have been unable to compete on a global scale through lack of means. With growth in its use and because it is not constrained by either time or location, the Internet has the potential for mass communication and advertising with negligible costs per customer. This leads to the following proposition.

Proposition 6: The use of the Internet increases SMEs' ability to devise global marketing strategies.

The Conceptual Model

The discussion and propositions above have argued that the use of the Internet could have a direct effect on an SME's export performance and a positive moderating effect on the relationship between information-related barriers and export performance. SMEs from the EAC could overcome information-related barriers by having easier access to information at a relatively low cost as a result, enhancing their export performance. Figure 1 shows the conceptual framework summarizing the above arguments and propositions.

The model indicates that information-related barriers may lead to poor export performance by SMEs. However, by using the Internet, SMEs are able to overcome some of these barriers and improve their export performance. In essence, Internet use has a moderating effect on the relationship between information barriers and SMEs' export performance. In addition, Internet use has some direct positive effects on SMEs' export performance. This implies that, even if using the Internet does not reduce or eliminate the information-related barriers encountered, it could still have a direct positive effect on export performance. And this may be the case especially for SMEs in the EAC who start exporting from inception. Thus, we argue that SMEs from the EAC that use the internet in their business operations will do better at exporting than those that do not.

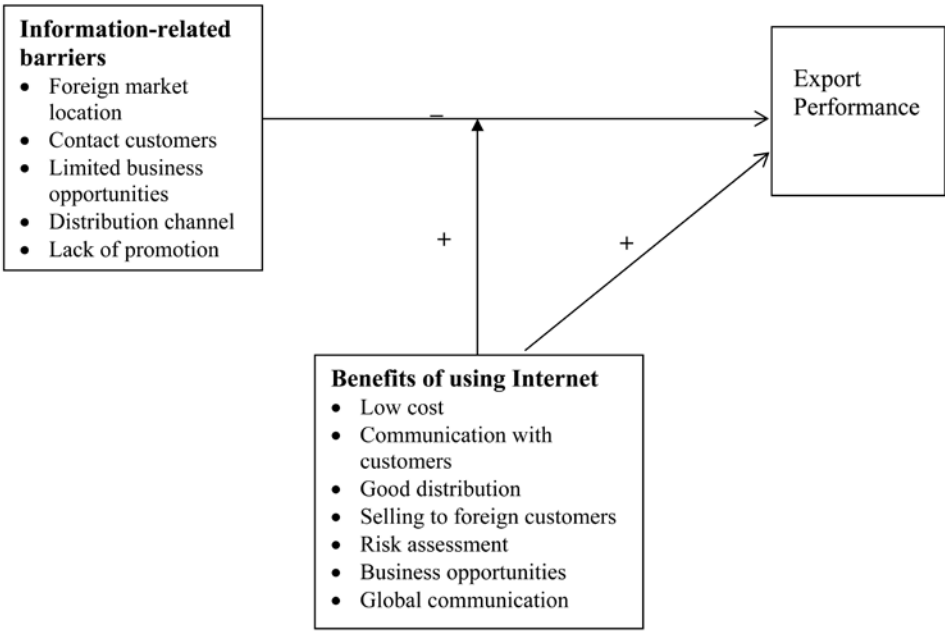

Figure 1. The effect of the internet on SMEs' export performance

This model has some limitations. First, it only considers information-related barriers and ignores other barriers. We do this purposely, since the focus of this study is on information-related barriers. We are aware that other barriers are faced by SMEs that affect export performance (Leonidou, 2004; Anderson, 2011). These barriers relate to market orientation, innovation, product development, management problems and lack of infrastructure. They have very little to do with the internet and much more to do with leadership, management and financial resources. Second, our model only looks at how export performance could be improved as a result of internet usage. From the literature, we know that SMEs' export performance is also affected by other factors such as managerial capacity, experience, resource availability and organizational culture (Myszak, 2010; Tesfom et al., 2006). These factors are not discussed in our model and future studies should take them into consideration.

Conclusion and Implications

This paper analysed the information-related barriers facing SMEs in the EAC, and how the Internet could help to overcome these barriers and improve export performance. The paper argues that, if SMEs were to use the Internet efficiently, their export performance would improve due to their exploitation of the distinctive features of the Internet. The paper has various implications.

Theoretical Implications

This paper contributes to the internationalization process model that was revised in 2009. In this model, Johanson & Vahlne (2009) argue that firms nowadays create new knowledge through exchanges and interactions via business networks of interconnected relationships. This paper contributes to this angle by showing how the Internet could be used as a means of interacting and forming business networks. When SMEs are able to form these networks, their participation in exportation and international markets is likely to improve. We further contribute to the discussion on the ability of SMEs to identify and utilize business opportunities through the internet. Similar to Johanson & Vahlne (2006), this paper argues that developing business opportunities and improving export performance through use of the Internet is an interactive process, characterized by a gradual increase in SMEs' learning and commitment to utilizing such opportunities.

The resource-based view of the firm suggests that firms can build competitive advantage through utilizing their unique resources (Barney, 1991). Teo & Pian (2003) show the positive relationship between the level of internet use and the competitive advantage of large firms. This paper contributes to this research area by showing how SMEs could use the internet to reduce information barriers and as a result build competitive advantage that would enable them improve exportation and compete internationally.

Practical Implications

This paper has specific implications for SMEs in the EAC. First, the EAC is making an effort to improve its participation in international business, and the use of the Internet could contribute to the success of this strategy. A report by the EAC (2011b) shows that the use of the internet and IT is expanding rapidly in the region. This paper argues that the EAC should make more effort to measure the growth rate of internet usage and identify how it could help SMEs within the community to participate in exporting and in other forms of internationalization.

Although the Internet has a direct effect on information-related problems, it could also indirectly affect firms' overall export performance as information is vital if they are to be successful in this regard. We argue that, because of the unique features of the Internet, it could act as a source of competitive advantage for SMEs, particularly those engaged in exporting. SMEs in the EAC should increase their use of the Internet, specifically social media and websites, to market their products and discover new business opportunities.

Although the Internet is important, it is not the only solution for exporting SMEs in the EAC. SMEs should be aware that, despite the Internet's advantages, there are costs associated with its use. Care should be taken in selecting what information to display and what not to display (Qualman, 2009). They should also realize that there is always competition out there and that, sometimes, putting a firm online may mean opening it up to greater competition. These could be the gains for not using the Internet.

Limitations and Future Research

This paper is limited as it lacks a thorough empirical aspect. However, the model and propositions developed here are a good foundation for an empirical study to be conducted in the East African setting in the future. Also, the paper focuses on the effects of the Internet on information-related barriers. The literature shows that there are other barriers and other factors that affect SMEs' export performance. Anderson (2011) examined other factors in the Tanzanian context, for example. Future research could utilize the arguments put forward in this paper, and borrow others from the related literature, to examine what other factors are important for EAC SMEs' participation in exportation.

We acknowledge the fact that we studied the Internet as a contribution to enhancing SMEs' export performance. It is possible that there is a reverse relationship in that the development of SMEs is the reason for the tremendous growth in Internet use. This is another limitation of our study and future empirical studies should take this into consideration.

This paper is also limited in that it only looks at the exportation mode of the internationalization process. There are other SMEs in the EAC that participate or would like to participate in licensing, franchising, joint venturing, strategic alliances and foreign direct investment (Owusu & Habiyakare, 2011). These SMEs may face different barriers that are worth investigating.

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Abstract (in Polish)

Małe i średnie przedsiębiorstwa odgrywają istotną rolę w gospodarkach krajów Afryki Wschodniej, wywierając pozytywny wpływ na wysokość dochodu narodowego i poziom zatrudnienia. Prowadzenie działalności eksportowej oferuje dodatkową możliwość rozwoju tych przedsiębiorstw i poprawę ich funkcjonowania. Jednocześnie przedsiębiorstwa doświadczają różnorodnych barier związanych z dostępnością i przepływem informacji zarówno przed jak i w trakcie prowadzenia działalności eksportowej. Celem pracy jest identyfikacja barier informacyjnych i podjęcie dyskusji nad wpływem internetu na ich przezwyciężanie. W oparciu o literaturę przedmiotu z zakresu internetu, międzynarodowego biznesu i małych przedsiębiorstw, autorzy formułują tezy i proponują model badawczy, który może być wykorzystany w przyszłych badaniach naukowych.

Słowa kluczowe: MSP, bariery informacyjne, Internet, eksport, Wspólnota Afryki Wschodniej.

The Optimal Timing of Strategic Action – A Real Options Approach

Gordon G. Sollars*, Sorin A. Tuluca*

Abstract

The possibility of a first-mover advantage arises in a variety of strategic choices, including product introductions, business start-ups, and mergers and acquisitions. The strategic management literature reflects ambiguity regarding the likelihood that a first mover can or will capture additional value. This paper uses a real options approach to address the optimal timing of strategic moves. Previous studies have modeled real options using either a perpetual or a European financial option. With these models, a strategic choice could only be made either without respect to a time frame (perpetual) or at a fixed point in time (European option.) Neither case is realistic. Companies typically have strategic options with only a limited time frame due to market factors, but companies may choose to act at any time within that constraint. To reflect this reality, we adapt a method for valuing an American financial option on a dividend paying stock to the real options context. The method presented in this paper proposes a solution for the optimum value for a project that should trigger a strategic choice, and highlights the value lost by not acting optimally. We use simulation results to show that the time frame available to make a strategic choice has an important effect on both the project value for when action should be taken, as well as on the value of waiting to invest at the optimal time. The results presented in this paper help to clarify the ambiguity that is found in the strategic management literature regarding the possibility of obtaining a first-mover advantage. Indeed, a first mover that acts sub-optimally could incur losses or at least not gain any advantage. A first mover that waits to invest at the right time based on the superior information supplied by models based on real options could be better positioned to obtain the benefits that might come from the first move.

Keywords: first-mover advantage, strategic action, real option analysis, simulation, optimal investment, dynamic programming.

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Introduction

The proper timing of strategic moves is widely discussed in the strategic management literature. The idea that a preferred value accrues to the "first mover" in a sequence of strategic actions is reflected in the very terminology commonly employed: first-mover advantage (FMA) theory. The possibility of a FMA arises in a variety of contexts, including product introductions, business start-ups, and mergers and acquisitions. This paper uses a real options approach to address the issue of the timing of strategic moves. We begin with a brief assessment of the theoretical and empirical studies of FMA. In the next section, we present a discussion of the idea of a real option. Previous treatments of real options typically have been restricted to options that never expire (perpetual), or that only can be exercised at one point in time (European). In the third section, we present a technique that can be used to value an option exercisable at any point in time up to a fixed expiration date (American). Subsequently, we use simulation results from the technique to illustrate how the issue of FMA could be addressed. Finally, we offer a summary and conclusion.

In a classic study of FMA, Lieberman and Montgomery (1988) suggest three sources of advantage: (1) technology leadership, (2) asset preemption, and (3) buyer switching costs or uncertainty. In their model of the sources of FMA, Lieberman and Montgomery point to FMAs as endogenously generated by a combination of "firm proficiency" and luck. In a subsequent treatment of FMA, Lieberman and Montgomery (1998) suggest that their earlier "proficiencies" language be viewed through the lens of the resource-based view (RBV) of the firm (Barney, 1986; Prahalad & Hamel, 1990; Rumelt, 1987; Wernerfelt, 1984).

The key assumption of the RBV is that firms in an industry have heterogeneous resources that are not perfectly mobile across firms (Barney, 1991). Here "resource" is very broadly construed to include anything that might conceivably add value to the firm. An implication of the RBV is that in order to expect to earn above-normal returns a firm must exploit resources already within its control (Barney, 1986). To the degree that the present control of relatively immobile resources may be unrelated to new strategic intentions, Lieberman's and Montgomery's model inputs of firm proficiency and luck tend to coalesce within the RBV. Although being a first mover is considered to be a potential source of advantage within the RBV (Rumelt, 1987; Wernerfelt, 1984), simply as a matter of logic, some heterogeneous, relatively immobile resources could lead to a first-mover disadvantage.

Early empirical studies finding FMA were conducted by the staff of the Federal Trade Commission, which found advantages in cigarette brands (Whitten, 1979) and prescription drugs (Bond & Lean, 1977). Makadok (1998) found FMA for product introductions in the money market mutual fund industry. Lee, Smith, Grimm, and Schomburg (2000) found FMA in new product introductions by testing shareholder wealth effects in the telecommunications, computer, and brewing industries.

Complementing the sources of FMA are factors that suggest that a first mover might suffer a disadvantage. In this regard, Lieberman and Montgomery (1988) list

free-rider effects; technological uncertainties or discontinuities; and "incumbent inertia" that could sap a first-mover's will to adapt to environmental changes. Theoretical models support the idea that the value of being a first mover is not unambiguous. For example, Suarez and Lanzolla (2007) present a model in which the pace of market and technology changes influences the likelihood of FMA. In the context of "product cannibalism", a particular subset of product introduction, Conner (1988) states conditions for the second mover to have an advantage.

Empirical studies also suggest that the first mover does not always hold an enviable position. Shankar, Carpenter, and Krishnamurthi (1998) conclude that a so-called "innovative" late mover can outsell the first mover. In the mergers-and-acquisitions context, Carow, Randall, and Saxton (2004) find that only the first mover with "superior information" captures any advantage. Kalyanaram, Robinson, and Urban (1995) find that being a first mover does not determine long-term industry survival.

Furthermore, a difficult challenge to studies purporting to find FMA is presented by the question of the proper measure of performance. Lieberman and Montgomery (1988) express concern that empirical studies attempting to address FMA are biased toward using market share, rather than profitability, measures due to the lack of disaggregated profit data. In a meta-analysis of 90 tests of FMA, VanderWerf and Mahon (1997) found that tests using market share were disproportionally more likely to find FMA than tests using profitability. Cui and Lui (2005) find no advantage in profitability in the pioneering of foreign investment in China. Using PIMS data, Boulding and Christen (2003) find a long-term profit disadvantage to the first mover at the business unit level. Thus, even where FMA is found, no additional value may have been created. In this paper, we assume that increasing firm value is preferred over simply increasing market share, an assumption fully consistent with the real options approach.

In summary, the strategy literature counsels caution regarding the value of moving first. However, even if contextual factors point to the desirability of being the first mover, the decision maker in such a case still faces the question of exactly when to make the first move. If analysis shows that there is little value to be lost by waiting, then the first move can be made at a time that is in some sense optimal, and additional value may be captured. A decision maker contemplating a strategic choice could benefit from an analysis quantifying the value that could be gained or lost by acting or not within some time frame. Concern over the possible loss of first-mover status might be unwarranted.

To assist the making of this kind of timing decision, we present an approach for determining the optimal timing of a strategic choice using the theory of real options. In this theory, strategic choices such as product introductions or mergers and acquisitions are analogized to the choice to purchase a financial options contract. Although the idea of a "real option" is not new, many managers remain unfamiliar with it. Furthermore, our methodology provides an approach that is more general in some respects than

what is typically found in the literature. The next section discusses the idea of a real option, beginning with its origins in the theory of financial options.

Real Options

Arrow and Fisher (1974) provide the classic interpretation of option value in the context of an investment decision: the value of utilizing more information before making an irreversible choice. They show that this value is always nonnegative. Henry (1974) is concerned with the same problem, but calls it the "irreversibility effect". The term coined by Arrow and Fisher (1974) was "quasi-option value". This quasi-option value is a measure of the worth of maintaining flexibility regarding when or whether to take some strategic opportunity.

The value of such an option is very difficult to quantify, and some would prefer to rely on qualitative reasoning and intuition when incorporating flexibility into their strategies. Hayes and Garvin (1982) recommend the use of judgment when analyzing possible strategic actions, without subjecting it to the "distortions" of quantitative methods. However, they were primarily concerned with the use of discounted cash flow valuation, which is known to systematically under value strategic choices. Although the limitations of quantification should not be ignored, intuitively, the maintaining of strategic flexibility must have some cost. Furthermore, a quantitative model may help identify where, and what kind, of intuitions are needed. The real options method we outline below is an example of such a model.

The task of quantifying the cost of flexibility became easier with the introduction of option pricing models from finance into corporate strategy. Mason and Merton (1985) are among the first to formalize the use of options pricing theory for the valuation of strategic flexibility; they might have coined the term of “real options” for such an exercise. The analogy between strategic choices and financial options, that either may be taken (exercised) or not, is straightforward. However, the concomitant benefit of a theory for pricing financial options, beginning with the Black-Scholes model (Black & Scholes, 1973), on strategic choices is substantial. Majd and Pindyck (1987) were among the first to discuss the application of real options to the value of waiting before making an investment decision. Later, Dixit and Pindyck (1994) were the first to apply a modern and rigorous approach to the problem of investment under uncertainty. They apply the concept of real options to several investment strategies, using the idea of a perpetual financial option to draw most of their conclusions. McDonald (1998), who makes an attempt to link rules of thumb to a more rigorous approach to investment decision rules based on real option analysis, uses perpetual options as well. Luehrman (1998a) and (1998b) attempts to demystify the concept of a real option using simple methodologies based on decisions that can be made only at specified moments, which corresponds to a European financial option approach. Even some of the more recent papers on the topic use perpetual options to produce results and comparative statics (Lukas & Welling, 2012).

The American financial option, which may be exercised at any time before maturity, is a more realistic model of the flexibility inherent in strategic choices. In the next section we present a technique for valuing a real option of the American type. Following that, we demonstrate that relaxing the perpetuity or European option assumptions in favor of the American leads to materially different conclusions regarding the value of waiting, and the optimal value at which a strategic opportunity should be taken.

Valuing an American-style Real Option

Strategic flexibility is usually valued with the help of stochastic dynamic programming or stochastic control, both nonlinear problems in themselves. The first refers to discrete time models, while the latter implies continuous time. Optimal behavior under uncertainty is described as a strategy (Lund, 1991) which defines the decision variables at each point in time as a function of the history up to, and, including that point. The stochastic control problem is based on the dynamic programming principle and the Hamilton-Jacobi-Bellman equation (Oksendal, 1991). The principle of dynamic programming (Duffie, 1988) states that the current value of a dynamic program is the maximum, over the set of possible current actions, of the current reward and the expected present value of the dynamic program over the next period.

When the variable of concern follows a Brownian motion, the dynamic problem leads to a parabolic partial differential equation with a free boundary condition. This problem does not have a closed-form solution. In general, numerical methods and most analytical approximations will generate solutions where the degree of accuracy depends on the number of iterations considered, as illustrated by Carr and Faguet (1994). Because the solution has no closed form, intuitive interpretations are usually not feasible.

To eliminate this complication, as mentioned earlier, most research has discussed various applications to real options using the perpetual, or, sometimes, the European, option. In the case of a perpetual option, the partial differential equation becomes an ordinary one, and finding a solution is a trivial matter. If we consider the case of real options, the assumption of perpetuity lacks realism simply because a strategic choice will not remain open forever.

Consider a decision maker, whether entrepreneur or corporate manager, who has the opportunity to take some strategic action, which we will call, simply, a “project”. The conditions that have created this particular project opportunity are not important. Any kind of resources or capabilities may be considered: superior technology, natural monopolies, patents, entrepreneurial insight, even corporate culture, to name a few. We adopt the following model (see Tuluca, 2000). The value of the project, ***P***, today is P_0 and can be regarded as the present value of some future cash-flows, discounted at rate ρ. The evolution of the project value, ***P,*** is uncertain over time. We assume that maintaining the flexibility concerning whether or not to take the project has a cost I_0. Furthermore, the decision maker faces a time limit, T, during which the choice to invest

I_0 must be made or the chance to take the project is lost. The use of the time limit T accommodates two aspects of strategic choice. First, the conditions that enable the possibility of a strategic action are unlikely to be maintained indefinitely. A patent or license may expire. A classic example is the concession on a natural resource, where resource exploitation has to begin within some period of time or the concession is lost. Second, competitors eager (or too eager) to capture any FMA may preempt the opportunity, as in the case of product introductions or mergers and acquisitions activities.

At each time t<T, the decision maker can chose to take the project or to postpone the decision in order to obtain more information about the evolution of P. Let this decision be our control variable *u*. Obviously, it can take just two values, 1 or 0, which correspond to investing I_0 or not taking the project. We designate by *V* the value at time 0 of the action to invest in the project at some future point in time. *V* can be thought as the value of investing with the flexibility of waiting. *V* is given by:

$$V(P,0) = \max_u \{ P(0) - I_0, E_0 [V(P,t) e^{-\rho t}] \} \quad [1]$$

At time zero, the value of investing in the project, *V(P,0),* is the maximum between the expected value of investing in the project at a time t, discounted to the present at a rate ρ, and the value of taking the project at time 0. Our maximization is governed by the control variable *u*, which in this case also represents our decision. From [1] it is clear that the value is always greater than or equal to zero. However, [1] is not helpful for solving the problem since no point in time is specified. A common technique is to rewrite [1] in two steps: one at time t and another at time t+ t. Equation [1] is then written as:

$$V(P,t) = \max_u \{ P(t) - I_0, E_t [V(P + \Delta P, t + \Delta t] e^{-\rho \Delta t} \} \quad [2]$$

The new formulation makes clear that the policy u that is chosen should be such as to be optimal for the future course of action. The formulation in [2] is the Bellman equation, and represents a dynamic programming problem (see for example, Lund, 1991). The problem starts at the time limit T and is worked backwards toward an optimal decision at time 0. This is a maximization problem over the control *u*. The problem is without a solution unless a process describing the evolution of ***P***, the project value, over time is specified. While many processes could be considered, the preferred specification is a geometric Brownian motion with a drift. The assumption of such a process can be sometimes unnecessary, but it is widely used in the literature.

The familiar form for the process describing ***P*** over time is:

$$dP = \alpha P dt + \sigma P dz \quad [3]$$

Where α is the rate of growth of project ***P***, is the instantaneous volatility, and *dz* is a Wiener process. To state the problem in continuous time, let t go to 0. The problem becomes:

$$V(P,t) = \max_u \{ P(t) - I_0, E_t [V(P + dP, t + dt)] e^{-\rho dt} \} \quad [4]$$

Expanding the second term on the right-hand side by Ito's Lemma[1] [5] yields:

$$(1 - \rho dt)[V(P,t)] + V_t(P,t)dt + V_p(P,t)\alpha P dt + \frac{1}{2} V_{PP} \sigma^2 P^2 dt \quad [6]$$

where terms going to 0 faster than dt are ignored. Substituting into [4] and restating the condition imposed by the maximization and the first term on the right-hand side gives:

$$\frac{1}{2}\sigma^2 P^2 V_{PP}(P,t) + \alpha P V_P(P,t) + V_t(P,t) - \rho V(P,t) = 0 \quad [7]$$

$$s.t. \quad V(0) = 0 \qquad (a)$$

$$V(P^*, t^*) = P^* - I_0 \qquad (b)$$

$$V_P(P^*) = 1 \qquad (c)$$

This restatement of the condition acknowledges that at some point in time a value could exist that will make the exercise of the option, i.e., taking the project, optimal. In other words, there might be a point where our control *u*=1. Conditions [7b] and [7c] are known as "value-matching" (Dixit & Pindyck, 1994) and "high contact" (Merton, 1973) conditions. These authors make the following point: if a value *P** for which the project is optimally taken, exists, then that value will be independent of the current value of ***P***. Furthermore, when and if the now current value of P reaches *P**, the value of taking the project now versus waiting is equal. Nothing further is to be gained by waiting.

Unfortunately the boundary condition is free, and therefore a closed-form solution does not exist. To analyze under what conditions the project should be taken before time T is reached, we start by temporarily changing the boundary conditions. We will impose the constraint that the project cannot be taken before time T. At such time the value of the project is

$$V(P,T) = \max[P(T) - I_0, 0] \quad [8]$$

1 If V is a function of P and t, Ito's Lemma says that V must follow a process described by:

$$dV = \left(\frac{\partial V}{\partial P}\alpha P + \frac{\partial V}{\partial t} + \frac{1}{2}\sigma^2 P^2 \frac{\partial^2 V}{\partial P^2}\right)dt + \frac{\partial V}{\partial P}\sigma P dz \quad [5]$$

This becomes the new boundary condition for [7], replacing [7b] and [7c]. The explicit form can be found if we transform the expectation into an integral and substitute P as a solution for the differential equation [3]. The solution is now (Ingersoll, 1987, p 312):

$$V(P,t) = e^{(\alpha-\rho)(T-t)}\ P\ N(p_1) - e^{-\rho(T-t)}\ I_0\ N(p_2) \qquad [9]$$

Here p_1 and p_2 are defined as:

$$p_1 = \frac{\ln \frac{P}{I_0} + (\alpha + .5\sigma)(T-t)}{\sigma\sqrt{T-t}} \qquad [10]$$

$$p_2 = p_1 - \sigma\sqrt{T-t}$$

From this point the problem becomes one of finding a relationship between α, the growth rate of the project, and ρ, the discount rate used to solve the control problem. In the theory of financial options this is usually solved by adjusting the growth rate for the appropriate level of risk and then discounting by the risk free rate, r. This standard procedure is derived either from a no-arbitrage argument (Merton, 1973), or from an equilibrium model such as the Capital Asset Pricing Model (CAPM) (Black & Scholes, 1973; Sharpe, 1964).

The usual contention is that a market-traded asset, perfectly correlated with the project under consideration, can be found (McDonald & Siegel, 1984, among others). Once this crucial assumption is made, the standard option pricing model framework with a solution of the same type as [10] can be considered in order to find a solution. The growth rate α is replaced by $r - \delta$, where δ is the return shortfall (McDonald & Siegel, 1984) of a non-traded asset, and ρ is replaced by the risk free rate. With this substitution, we face the classic problem of an option written on a dividend paying stock (see Merton, 1973). That there are only two cases where such a problem has a closed-form solution is well known: when either the option is European (it can be exercised only at a specified point in time); or when the option is perpetual and time disappears from the differential equation [7]. In the case of an American financial option (which can be exercised at any point in time until its maturity) the solution is a numerical or analytical approximation.

Despite the widespread acceptance of the “traded-asset" methodology for the evaluation of real options, the underlying assumption is problematic. A traded asset correlated with a future project is often, if not usually, impossible to find. In addition, the real option cannot really be traded[2]. When the decision maker has a real option, more often than not the project in question is a completely new idea for which no analogous asset exists. In this situation, the procedure of adjusting the project growth

2 Arguably in the mergers and acquisitions context the strategic options are “traded”, but the frequency of such trades is differs greatly from the continuous time assumption that the option pricing model assumes.

rate and then discounting by the risk-free rate is a misleading exercise. However, the derivation of [10] did not imply either the "no-arbitrage" argument or an equilibrium model of the CAPM genre. Therefore, [10] is still a valid solution for the real option problem of the value of waiting, when the option is of the European type. Even if, conceptually, financial and real options have their differences, the problems of valuing the two remain related since the solutions have the same general formula, when a closed-form formula can be found.

When the real option can be exercised at any time before maturity, however, the solution given by [10] is no longer appropriate; rather, it is necessary to solve a system given by [7]. Barone-Adesi and Whaley (1987) (BAW) developed an interesting approximation for the solution of [7] in the case of an American financial option. Because of the similarity between the financial and real options the same procedure can be applied to determine the value of waiting to make a strategic choice.

The solution proposed by BAW provides several benefits. First, their approximation has the advantage of being computationally inexpensive and relatively simple enough to be understood by managers. The need to make the real option problem easier to understand and to offer a simpler formulation for managers has been recognized several times (Copeland & Tufano, 2004; Luehrman, 1998a, 1998b). Second, the optimum value of the project for when action should be taken is computed as part of the derivation, and therefore no separate algorithm for determining this value is needed. Third, even though only an approximation, the formulation in BAW holds up well when compared to more complex approximations. BAW compared their approximation with the implicit finite-difference method and the approximation proved to be quite accurate. A short summary of the BAW approximation is presented below.

Using BAW notational substitutions: $M = 2\rho/\sigma^2$, $N = 2\alpha/\sigma^2$, and $\tau = T - t$, the time remaining to expiration from present, in place of t, the time evolving from time 0 to present the following is an approximate solution for [7]):

$$V(P,t) = v(P,t) + A_2(P / P^*)^{q_2} \quad for \quad P < P^* \quad V(P,t) = P - I \quad for \quad P \geq P^* \qquad [11]$$

$$A_2 = P^* / q_2\{1 - e^{(\alpha-\rho)\tau} N[p_1(P^*)]\} \qquad [12]$$

$$q_2 = .5[-(N-1) + \sqrt{(N-1)^2 + 4M/N}] \qquad [13]$$

*P** is the solution to the following implicit equation:

$$P^* - I = v(P^*, t) + \{1 - e^{(\alpha-\rho)\tau} N[p_1(P^*)]\} P^* / q_2 \qquad [14]$$

and *v(P,t)* is given by:

$$v(P,t) = e^{(\alpha-\rho)\tau} \; P\,N(p_1) - e^{-\rho\tau} \; I_0 \; N(p_2) \qquad [15]$$

where p_1 and p_2 are defined as:

$$p_1 = \frac{\ln P(0)/I_0 + (\alpha + .5\sigma)\tau}{\sigma\sqrt{\tau}} \qquad p_2 = p_1 - \sigma\sqrt{\tau} \qquad [16]$$

The BAW approximation allows a new insight into the real options problem of the value of waiting to make a strategic choice, thus providing a more realistic approach to the real world. At the same time, the value at which the project is optimally taken can be obtained as a by-product of the approximation. *P** represents a "trigger" value for the decision whether or not to take the project. As the value of the project *P* evolves during time until T due to the availability of more information, should *P* ever become equal to, or exceed, *P**, then the optimal time for action has been reached.

The real options methodology provides a way to value strategic flexibility. Having strategic flexibility could be misused, and therefore a favorable situation could be lost. Knowledge of the value of the real option and of the value of the project when this real option can be exploited at its maximum can provide the decision maker with vital information. The model proposed in this paper has three distinctive advantages over the previous literature in that it: (1) avoids the problem of finding a traded asset correlated with the project; (2) allows for an analytical solution of a real option with an American, as opposed to a perpetual or European, format; and (3) provides a solution for the optimum value for the exercise of the real option.

An objection could be raised to the validity of such an analysis in a setting where the rates of project growth and discount, as well as the volatility of *P,* are only subjective or intuitive judgments that are not subject to market verification. A counterargument can be made as follows. Consider a company valuing a variety of projects. If all of them are analyzed by the same decision maker, then the same subjectivity or intuition is applied to all the projects. Thus, from the perspective of the decision maker, the decision to take some over others can be optimal even if subjective. The fact that the analysis does not rely upon assets traded in the marketplace does not imply the decision is not optimal based upon the available information. The market is in no position to evaluate the real option the decision maker has, since most of the real options are on projects which are not public knowledge.

Real Options Perspective on FMA

This section presents some numerical examples that demonstrate the importance of the time constraint for understanding the value of strategic flexibility. Consider a project P with a current present value, P0, of $100 from all its future cash flows. The investment

I0 necessary to take this project is also $100. Obviously, the ratio P0/I0 is 1. We will further assume a discount rate, r, of thirty percent. Let q be the difference between the discount rate r and the rate of growth a of the project, and σ be the standard deviation (volatility) of P. P* is the present value of all the future cash flows for which the project is optimally taken at a time t<T. Calculated as presented in the previous section, *P** is the "trigger" value indicating when and if the time to take the project has been reached.

Table 1, Panel A varies the time limit T from three to twelve months, and q from .01 to .09, for a fixed σ = .35. For all values of q considered, the time to maturity has a direct relationship on P^*/I_0. As the opportunity to take the project narrows, less and less value for ***P*** is required to trigger action. The ratio varies from about four to forty depending on the values of T and q considered. The time effect is not as powerful as the q effect. For instance, a doubling of time from six months to twelve months increases the value by 8% to 10% across q, while a doubling of q increases the effect on the value about two times. Nevertheless, Panel A shows the selection of a time limit T can influence the optimal value for taking the project. More importantly, it shows that use of the BAW method can quantify the effect of having the flexibility of choice in the time limit T.

Panel B shows the effect of varying both the time constraint of the option and the effect of volatility (with the value of q fixed at .05) on P^*/I_0. Here, the effect of the time constraint is not only comparable to, but even greater than, the effect of the volatility of the project. The range of both effects is between ten percent and twenty percent. The implication is that the time constraint could become more important than the effect of volatility for the value of *P**. For instance, an increase in the time limit T, the time of expiration of the option, from three to twelve months has almost the same effect as an increase in uncertainty, as measured by the volatility of ***P*** from twenty percent to fifty percent. Most managerial decisions focus on uncertainty. Yet, this simulation provides evidence that the time frame available for action is equally important.

Given that the selection of the time limit T exerts an influence comparable to that of σ, the selection of T should be made with equal care. When dissimilarities between the traded-asset assumption and the real-world situation predominate, the value chosen for σ is a guess that must be based largely upon intuition. In that case, sensitivity analysis by varying σ can help to determine how closely σ must be known for its value to affect the strategic decision. To the degree that the time limit T on a strategic decision is flexible, the BAW method allows the sensitivity of the decision to be measured. Figures 1 and 2 summarize in a succinct way the sensitivities discussed in both panel A and panel B of Table 1.

A decision maker who initially calculates a relatively large value of *P** relative to P_0 has a reason to wait before committing to be the first mover. On the other hand, if P_0 is already relatively close to *P**, then little value might be placed at risk by acting immediately and seizing first-mover status. However, in order to assess this choice, the value of taking the project *P* with the flexibility of waiting, *V*, must be computed, as in Table 2 below.

Table 1. The influence of the time constraint on P^*/I_0 for various volatilities (σ) and q (difference between the discount and the growth rate) combinations

Panel A (constant σ=.35)					
	q				
T	**.01**	**.03**	**.05**	**.07**	**.09**
3	34.13	11.36	6.81	4.86	3.78
6	36.26	12.05	7.21	5.14	3.99
9	38.18	12.66	7.6	5.37	4.16
12	40.02	13.23	7.88	5.59	4.32

Panel B (constant q=.05)				
	T (months)			
σ	**3**	**6**	**9**	**12**
.20	6.48	6.74	6.98	7.22
.25	6.59	6.89	7.16	7.42
.30	6.70	7.05	7.36	7.64
.35	6.81	7.21	7.56	7.88
.40	6.93	7.38	7.77	8.13
.45	7.05	7.56	8.00	8.39
.50	7.17	7.74	8.23	8.67

Table 2 presents the effects of varying time, along with the other two parameters, on *V*. Panels A and B show that the time constraint is much more important than the effect of q or σ. While increasing q increases the value of *V* fractionally, the time effect increases the value of *V* between two and three times. The same result holds when the effect of time is compared with the effect of volatility. Table 2 helps to quantify how having more time to make the decision can dramatically affect the value of the strategic action. That extending the time to expiration increases the value of the option is not new. However, that the time constraint has effects more powerful than those of uncertainty or the difference between the discount and the project growth rate has not been presented in the previous literature. Figures 3 and 4 show the sensitivity of *V* to T, q and σ.

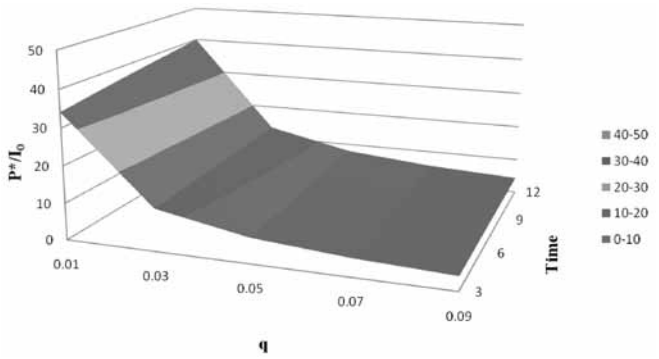

Figure 1. P*/I0 sensitivity with time and the difference between discount and growth rates

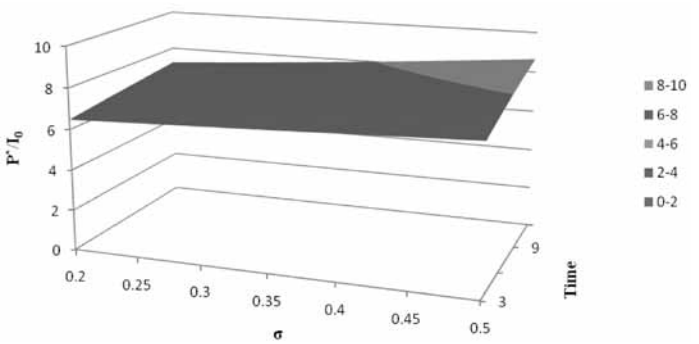

Figure 2. P*/I0 sensitivity with time and volatility

Table 2. The influence of the time constraint on V, the value of investing in the project with the flexibility of waiting, for various volatilities (σ) and q (difference between the discount and the growth rate) combinations

Panel A (constant σ=.35)					
			q		
T	**.01**	**.03**	**.05**	**.07**	**.09**
3	10.76	10.42	10.08	9.76	9.43
6	17.36	16.61	15.89	15.18	14.50
9	23.11	21.93	20.79	19.69	18.64
12	28.31	26.68	25.19	23.63	21.21

Panel B (constant q=.05)				
	T (months)			
σ	**3**	**6**	**9**	**12**
.20	7.53	12.8	17.54	21.89
.25	8.34	13.74	18.49	22.79
.30	9.2	14.78	19.59	23.89
.35	10.09	15.89	20.79	25.12
.40	10.99	17.04	22.06	26.45
.45	11.9	18.21	23.37	27.84
.50	12.81	19.4	24.72	29.27

The use of the BAW method in this context allows the effect, here on V, of the time limit T to be quantified. Table 1 suggests that there can be a penalty for the first mover being too eager and moving before P* is reached. Yet, the time constraint does not have much of an effect on the value of P*. Table 2 confirms that a first mover that moves before the optimal time could incur a great loss. The value to be lost by taking the project before P* can grow dramatically as T, the time limit for the decision, increases. To the extent that the time constraint is flexible, the value of the option from the gain due to waiting can be calculated, and a sensitivity analysis performed, as demonstrated in Figures 3 and 4.

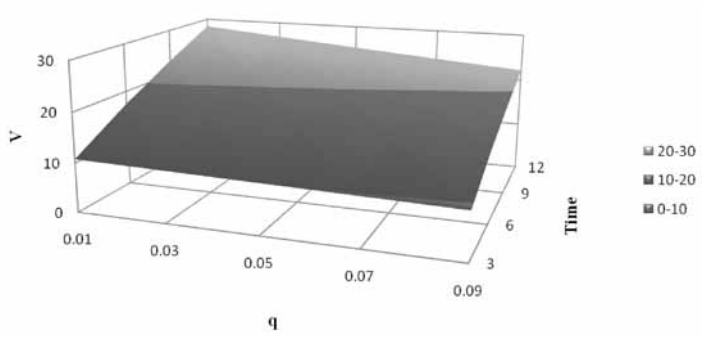

Figure 3. V as a function of the difference between discount and growth rate and time

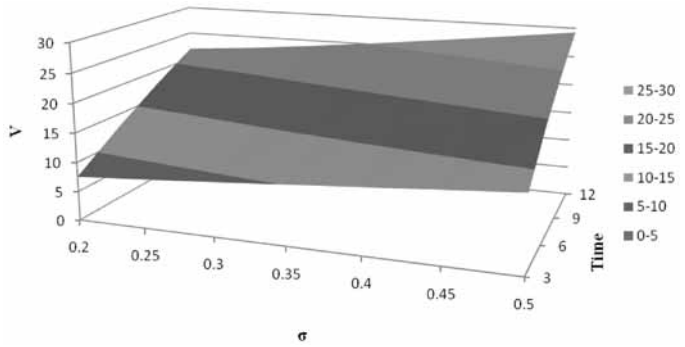

Figure 4. V as a function of time and volatility

Summary and Conclusion

The theoretical and empirical literatures of FMA are ambiguous regarding the likelihood that a first mover will obtain an advantage. Lieberman and Montgomery (1988) explain FMA as a function of firm proficiencies and luck. Subsequently, Lieberman and Montgomery (1998) tie their notion of firm proficiencies to the RBV of the firm. A fundamental of assumption of the RBV is that firms are able to gain competitive advantage only from resources they already happen to control (Barney, 1986). With theoretical studies highlighting the importance of luck and chance factors in attaining FMA, a method for quantifying the effects of timing on the value of a strategic decision with flexibility is welcome. Furthermore, some empirical studies point to the need for superior information in order to properly exploit first-mover status (Carow et al., 2004). We present a method for obtaining more information about the optimal time to take a strategic action. In some sense, our results validate Kalyanaram et al. (1995) who find that being a first mover does not determine long-term industry survival. Clearly, if the first mover does not move optimally, its long term survival could be compromised by the taking of a value-destroying project. While there is potential for an FMA strategy, it is not always the case that the potential is realized. Our results support, for instance,

Shankar et al. (1998) who conclude that a so-called "innovative late mover can outsell the first mover. This is entirely possible if it is the late mover who takes the project at the optimal time.

To provide some quantitative grounding for optimal action, we use a dynamic programming approach to derive the value of a project with the option to wait for a fixed time limit. Using the analogy between the valuation of the project and the valuation of an American call, and exploiting the BAW approximate solution, numerical examples are provided. The examples show that the time to expiration of the right to take the project has a dramatic influence on the value of the project. This result, while implied by some previous earlier research (Ingersoll & Ross, 1992, for example), is usually not discussed in the literature. While previous research focused on the influence of either the interest rate (Ingersoll & Ross, 1992) or of uncertainty (Leahy & Whited, 1996), this paper highlights the importance of the time constraint with respect to the other two factors. The numerical and graphical simulations make obvious that the time factor has important implications for strategic choice.

Apart from this new result, we formalize a simple method of computing the value of projects with the option to wait, which at the same time provides the optimal value at which the project should be started. This can be a convenient tool for the valuing of new product introductions, mergers and acquisition, small business start-ups, or for use by patent rights holders (see Damodaran, 1996, for a simpler version of this example). Second, the approach is independent of the complications posed by the no-arbitrage or equilibrium conditions usually employed in financial options theory. Freedom from these assumptions makes sense in the entrepreneurial world of business startups and product introductions, where business intuitions concerning returns and uncertainty can play an important role.

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Abstract (in Polish)

Możliwość uzyskania przewagi "pierwszego ruchu" pojawia się w kontekście różnorodnych decyzji o charakterze strategicznym, takich jak wprowadzenie na rynek nowego produktu, podjęcie nowej działalności gospodarczej czy też fuzje i przejęcia. Literatura z zakresu zarządzania strategicznego nie charakteryzuje w sposób jednoznaczny prawdopodobieństwa uzyskania dodatkowej wartości z tytułu realizacji "pierwszego ruchu". Niniejsza praca proponuje podejście oparte o metodologię wyceny realnych opcji (ang. real options approach) dla wyznaczenia optymalnego momentu dla realizacji strategicznego posunięcia (realizacji projektu inwestycyjnego). W odróżnieniu od proponowanych w literaturze podejść z zakresu wyceny realnych opcji, autorzy proponują metodę opartą o wycenę opcji finansowej typu Amerykańskiego. Metoda, oparta o znany model aproksymacyjny zaproponowany przez Barone-Adesi i Whaley (1987), pozwala na wyznaczenie wartości projektu w terminie optymalnym dla jego realizacji i wartości wstrzymania się z podjęciem decyzji o realizacji projektu do terminu optymalnego (wartość opcji "wait and see"). Rezultaty symulacji wskazują na istotną rolę długości horyzontu czasowego, który jest dostępny dla podjęcia decyzji o strategicznym posunięciu, zarówno dla wyceny wartości projektu inwestycyjnego jak i wartości opcji – możliwości przesunięcia decyzji na poźniejszy optymalny termin.

Słowa kluczowe: przewaga pierwszego ruchu, działania strategiczne, analiza opcji rzeczywistych, symulacja, optymalna inwestycja, programowanie dynamiczne.