The interaction between operational flexibility and financial flexibility

Onur BOYABATLI
Singapore Management University, oboyabatli@smu.edu.sg

Tiecheng LENG

Foundations and Trends® in Technology, Information and Operations Management

The Interaction between Operational Flexibility and Financial Flexibility

Suggested Citation: Onur Boyabatlı and Tiecheng Leng (2017), "The Interaction between Operational Flexibility and Financial Flexibility", Foundations and Trends® in Technology, Information and Operations Management: Vol. 11, No. 1-2, Special Issue on Integrated Risk Management in Supply Chains. Edited by P. Kouvelis, L. Dong and D. Turcic, pp 13–31. DOI: 10.1561/0200000077.

Onur Boyabatlı
Lee Kong Chian School of Business,
Singapore Management University
oboyabatli@smu.edu.sg

Tiecheng Leng
Lingnan College, Sun Yat-sen University
China
lengtch@mail.sysu.edu.cn

now
the essence of knowledge
Boston — Delft

Contents

The Interaction between Operational Flexibility and Financial Flexibility

Onur Boyabatlı[1] and Tiecheng Leng[2]

[1]*Lee Kong Chian School of Business, Singapore Management University; oboyabatli@smu.edu.sg*
[2]*Lingnan College, Sun Yat-sen University, China; lengtch@mail.sysu.edu.cn*

ABSTRACT

This paper examines the interaction between operational flexibility and financial flexibility in a multi-product business unit that makes operational decisions based on financial resources provided by its parent company (or headquarters). We capture operational flexibility through investment in flexible technology and financial flexibility through higher availability of financial resources. We consider the flexible-versus-dedicated technology choice and capacity investment decisions of a two-product business unit under demand uncertainty in the presence of budget constraints. The unit operates under a capital budget for financing the capacity investment, and an operating budget, which is uncertain in the capacity investment stage, for financing the production. We investigate how financial flexibility in the capacity investment stage (as captured by the stringency of the capital budget) and financial flexibility in the production stage (as captured by the likelihood of having sufficient operating budget to fully cover the production cost) shape the optimal technology choice. We identify the critical role that the relative capacity intensity (the ratio of unit capacity cost to total unit capacity and production cost) of each technology plays. Our results have implications about how

Onur Boyabatlı and Tiecheng Leng (2017), "The Interaction between Operational Flexibility and Financial Flexibility", Foundations and Trends® in Technology, Information and Operations Management: Vol. 11, No. 1-2, Special Issue on Integrated Risk Management in Supply Chains. Edited by P. Kouvelis, L. Dong and D. Turcic, pp 13–31. DOI: 10.1561/0200000077.

to deploy technologies with different capacity intensity profiles, which are shaped by automation level or plant location choices.

1

Motivation and Description of the Problem

This paper examines the interaction between operational flexibility and financial flexibility in a multi-product business unit that makes operational decisions based on financial resources provided by its parent company (or headquarters). We capture operational flexibility through investment in flexible technology and financial flexibility through higher availability of financial resources. The results in this chapter are originated from our companion paper, Boyabatlı *et al.* (2016).

Multi-product business units often use product-flexible resources (flexible technology) to cope with demand uncertainty. Compared to product-dedicated resources (dedicated technology), these flexible resources can manufacture multiple products on the same capacity, and provide the ability to reallocate this capacity between products in response to demand realizations. This capacity-pooling benefit of the flexible technology is a hedge against demand uncertainty. Flexible technology investment is prevalent in many industries, including automotive, pharmaceutical, consumer electronics and semi-conductor manufacturing (Eynan and Dong, 2012). Given the capital-intensive nature of these industries, one of the key determinants of the technology investment is the availability of financial resources to cover the costs incurred for capacity investment and production. A common practice for business units who are responsible for making these operational decisions is to rely on budgets allocated by the parent company to finance their operational investments and subsequent operations (Stein, 1997). Consider, for example, the automotive industry. Major auto manufacturers have multiple business units controlling several manufacturing facilities (Data-Monitor, 2009), where the capacity investment and production decisions are made. The primary source of financial resources for these business units is their parent company. In the operations management literature, as also highlighted in Van Mieghem (2003), the majority of papers focusing on technology investment assume that these business units can make the operational decisions safe in the knowledge that the parent company can provide sufficient financial resources to support these investments—that is, there is always full financial flexibility.

In practice, business units do not have full financial flexibility and face budget constraints for their capital expenditure and operating expenditures. In particular, the capacity investment is financed through a capital budget which covers the procurement cost of the physical assets such as land and machinery. The subsequent production activities are financed through an operating budget, which covers the factory related costs such as overhead, raw material procurement, machining and labor. Moreover, the operating budget remains uncertain at the time of the capacity investment and may become constraining in the production stage for two main reasons. First, the parent company may fund the business unit at a lower level than anticipated due to adverse cash flow shocks, which can be a result of, for example, intensified competitive pressure or tighter external financing conditions; or due to a reallocation to a more profitable business unit (Scharfstein and Stein, 2000). Second, the operating costs (such as the procurement cost) may increase in the interim or a cost reduction target may not be met. Consider, again, the automotive industry. Because the key inputs for car manufacturing (such as steel, aluminum and plastics) are commodities, volatility in their prices often lead to a spike in procurement cost (Bream and Marsh, 2008). Moreover, our discussions with automotive executives indicate that the parent company plans for the operating budget after incorporating a cost reduction target for the business unit, and it is not uncommon to observe such targets unachieved in practice. As a result, the planned operating budget can be insufficient for the business unit.

The financial flexibility of the business unit is determined through the stringency of its budget constraints. Because the capital expenditure and operating expenditures are funded by different budgets we differentiate between the financial flexibility in the capacity investment stage and the financial flexibility in the production stage. Our first objective is to study the effect of financial flexibility in the capacity investment stage. As the capital budget gets tighter the business unit becomes less financially flexible in this stage. As discussed in the literature on business unit financing (see Stein (2001) for an excellent review), one of the key determinants of the capital budget is the ability of the parent company to raise capital from external markets. In the aftermath of the global financial crisis in 2007, the unavailability of external capital has become an issue for manufacturing firms all around the world (see, for example, Pimlott, 2009); "credit terms have tightened or available credit has disappeared altogether." (Matson, 2009). These external financing problems have led to a shrinking of the financial resources available for operational investments as documented empirically (Chava and Purnanandam, 2011). Motivated by this observation, our first research objective is to investigate how the tightening of the capital budget shapes the flexible-versus-dedicated technology choice.

Our second research objective focuses on the operating budget uncertainty. As discussed above, the operating budget, which is uncertain at the time of capacity investment, may become constraining in the production stage. We call the likelihood of the business unit having a sufficient operating budget to fully cover the operating costs as this business unit's financial flexibility in the production stage. Our second research objective is to investigate how this financial flexibility affects the flexible-versus-dedicated technology choice.

The most relevant literature to this paper is the literature on stochastic capacity and technology investment in multi-product firms. Papers in this stream consider investment in flexible and dedicated capacity, and barring two exceptions (Boyabatlı and Toktay, 2011, Chod and

Zhou, 2014),they do so in the absence of financial constraints.[1] Yet a business unit relies on limited budgets allocated by its parent company to make this capacity investment and subsequent production decisions. Our companion paper Boyabatlı *et al.* (2016) is the first paper that studies how the capital budget constraint and the operating budget uncertainty jointly shape the flexible-versus-dedicated technology choice and the optimal capacity investment with each technology.

Two other streams of literature are related to this paper due to their incorporation of financial constraints. Following the seminal work of Modigliani and Miller (1958), there is a vast amount of research in the Corporate Finance literature that investigates the interaction between a firm's operational investments and financing policies in a variety of settings. The main focus of these papers is on financial issues; therefore, they have strong modeling assumptions concerning the firm's operations. In the Operations Management literature, Babich and Sobel (2004), Buzacott and Zhang (2004) and, more recently, Babich (2010) and Yang and Birge (2017) analyze similar issues with a stronger formalization of operational decisions. We refer the reader to Yang *et al.* (2015) for a review of papers in this stream. All these papers analyze the impact of an endogenous capital budget constraint in a single-product firm. The budget constraint is endogenous as it is determined by the interaction between the capacity investment and the external capital markets. These papers establish the value of integrating financing and capacity investment decisions. While we do not preclude external financing at the parent company level, this is not the focus of our analysis. Our scope is the business unit that makes the operational decisions based on the budget allocated by its parent company. Therefore, unlike these papers, we do not study the value of integrating financing and capacity investment decisions. Instead, we extend the analysis of the impact of budget constraint in two significant ways: First, we consider an operating budget, which is uncertain in the capacity investment stage, and can be constraining in the production stage. Second, we consider a multi-product business unit where the technology choice also matters.

[1] We refer the reader to Boyabatlı *et al.* (2016) for an extensive review of the literature that study flexible capacity investment in the absence of financial constraints.

2

Modelling Approach and Methodology

We propose a stylized model in which we consider a business unit of a parent company that produces and sells two products under demand uncertainty so as to maximize its expected profit. The business unit operates under two separate budgets allocated by the parent company; a capital budget for financing the capacity investment and an operating budget for financing the subsequent production, which is uncertain at the capacity investment stage. We consider a two-stage model. In the first stage, the business unit makes the flexible-versus-dedicated technology choice (dedicated D versus flexible F) and the capacity investment decision with respect to a capital budget constraint and in the face of demand and operating budget uncertainty. In the second stage, the business unit determines the production quantities after these uncertainties are resolved. The flexible technology has a single resource that is capable of producing two products and the dedicated technology consists of two resources that can each produce a single product. Each technology $T \in \{D, F\}$ is characterized by a unit capacity cost c_T and a unit production cost y_T that is identical for both products. The sequence of events is presented in Figure 2.1.

For modelling of the capital and operating budgets, we denote capital budget by B_1. Paralleling practice, we assume that any leftover capital

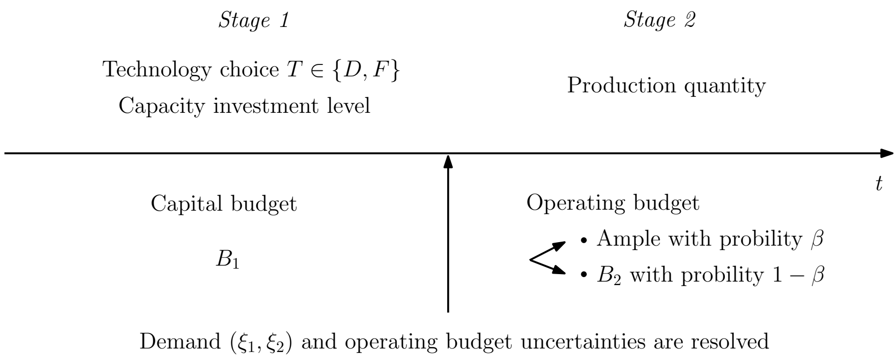

Figure 2.1: Timeline of Events.

budget from the capacity investment stage cannot be used to finance the production. For the operating budget, which is common for both products, we choose a two-point characterization: The operating budget is ample with probability $\beta \in [0, 1]$, and it is B_2 with probability $(1-\beta)$. By ample, we mean this budget is sufficient to finance the production at a level that fully utilizes the highest capacity investment level that can be made with the capital budget B_1. B_2 is insufficient to finance this production volume, i.e. $\frac{B_2}{y_T} < \frac{B_1}{c_T}$ for $T \in \{D, F\}$. Depending on the capacity level chosen in stage 1, B_2 may or may not be insufficient to fully utilize this capacity level. If B_2 is insufficient, then the production is budget constrained with probability $(1-\beta)$.

We capture the business unit's *financial flexibility in the capacity investment stage* through the stringency of the capital budget constraint B_1. As B_1 increases, the business unit is more financially flexible in the capacity investment stage, and it is fully financially flexible when B_1 is sufficient to finance the first-best (budget-unconstrained) capacity investment level with each technology. Similarly, we capture the business unit's *financial flexibility in the production stage* through the likelihood that the firm is able to find an operating budget that is sufficient to fully cover the operating costs for any capacity level, i.e., β. As β increases, the business unit is more financially flexible in the production stage, and it is fully financially flexible when $\beta = 1$.

Price-dependent demand for each product i is represented by the same iso-elastic inverse-demand function $p_i(q_i;\xi_i) = \xi_i q_i^{1/b}$. Here, $b \in (-\infty, -1)$ is the constant price elasticity of demand, p_i denotes the price, q_i denotes the quantity, and ξ_i represents the demand risk in market i. The demand uncertainty $\tilde{\boldsymbol{\xi}}' = (\tilde{\xi}_1, \tilde{\xi}_2)$ has a positive support with probability density function $f(\xi_1, \xi_2)$. We assume that $\tilde{\boldsymbol{\xi}}$ follows a symmetric bivariate distribution with mean $\mathbb{E}[\xi_1] = \mathbb{E}[\xi_2] = \mu_\xi$ and covariance matrix $\boldsymbol{\Sigma}$ with $\boldsymbol{\Sigma}_{ii} = \sigma^2$, where σ denotes the standard deviation, and $\boldsymbol{\Sigma}_{ij} = \rho\sigma^2$ for $i \neq j$ where ρ denotes the correlation coefficient. We assume that the firm adheres to a production clearance strategy, that is, choosing the production level so as to fully utilize the available production capacity. The available production capacity is determined by the two resources required for production: the capacity invested at stage 1 and the realized operating budget. With the production clearance strategy, the firm optimally chooses how to allocate the maximum available production capacity between the two products.

Flexible technology has a single resource with capacity level K_F that is capable of producing two products. Dedicated technology has two resources that can each produce a single product. Because we assume symmetric products, the firm optimally invests in identical capacity levels for each product with dedicated technology. Therefore, a single capacity level K_D is sufficient to characterize the capacity investment decision. For tractability, we assume $\frac{c_D}{c_D+y_D} > 1 - \frac{\mathbb{E}[\min(\tilde{\xi}_1,\tilde{\xi}_2)]}{\mu_\xi}$.

Based on this two-stage model, we first solve for the optimal capacity level and production quantities with each technology. We then examine the optimal technology choice in a budget-constrained environment and how this choice is affected by a lower financial flexibility in the capacity investment or production stage. To provide analytical results and generate sharper managerial insights, we introduce a reformulation in our model. To characterize technology T, instead of (c_T, y_T), i.e. the unit capacity and production costs, we use (η_T, α_T) where $\eta_T = c_T + y_T$ and $\alpha_T \doteq \frac{c_T}{c_T+y_T}$. In this formulation, η_T denotes the unit (aggregate) investment cost of technology T. We call $\alpha_T \in [0, 1]$ the capacity intensity and $(1 - \alpha_T)$ the production intensity of the technology T. Because the former measure uniquely defines the latter, we only focus on the capacity intensity in our analysis. It is easy to establish that the optimal expected profit strictly decreases in the unit investment cost with each technology. Therefore, for a given unit investment cost η_D of dedicated technology, there exists a unique unit investment cost threshold $\overline{\eta}_F(\eta_D)$ for flexible technology such that it is optimal to invest in flexible technology when $\eta_F \leq \overline{\eta}_F(\eta_D)$, and in dedicated technology otherwise. In the presence of budget constraints, $\overline{\eta}_F(\eta_D)$ captures the capacity-pooling value of the flexible technology and the relative impact of the capital budget and the operating budget uncertainty on each technology. Throughout our analysis, we assume that the capacity intensity is (weakly) larger with the flexible technology, i.e. $\alpha_F \geq \alpha_D$. To better delineate the intuition behind our results, we first focus on the special case with identical capacity intensities, i.e. $\alpha_F = \alpha_D$. We then investigate how our results are impacted as α_F increases.

To understand how financial flexibility in the capacity investment stage impacts the optimal technology choice, we conduct sensitivity analysis to investigate how $\overline{\eta}_F(\eta_D)$ changes in the capital budget B_1. Similarly, to understand how financial flexibility in the production stage impacts the optimal technology choice, we conduct sensitivity analysis to investigate how $\overline{\eta}_F(\eta_D)$ changes in β. When analytical results are not attainable, we resort to numerical experiments. In these experiments, we assume that $\tilde{\boldsymbol{\xi}}$ follows a symmetric bivariate normal distribution. We use the following baseline parameter values: $\mu_\xi = 10$, $\sigma_\xi = 4\%$ of μ_ξ, $\rho = 0$, $\eta_D = 3$, $\alpha_D = 0.7$, $\alpha_F = \alpha_D + l$, where $l = \frac{1-\alpha_D}{4}$, $B_2 = k * 2(1-\alpha_D)\eta_D K_D^u$, where $K_D^u \doteq \left(\frac{(1+\frac{1}{b})\mu_\xi}{c_D+y_D}\right)^{-b}$ denote the budget-unconstrained capacity investment level, $k = \frac{1}{10}$ and $b = -2$. We consider a large set of values for the parameters of interest, β and B_1. In particular, we choose 40 β values in $[0,1]$, and assume $B_1 = m * 2\alpha_D\eta_D K_D^u$, where m takes 40 values between $1.1k$ and 0.9, which satisfies our assumption $\frac{B_1}{\alpha_D} > \frac{B_2}{1-\alpha_D}$. To ensure robustness with respect to demand parameters, capacity intensity and operating budget, we vary the model parameters as follows: $\mu_\xi \in \{10, 20, 30\}$, $\sigma_\xi \in [4\%, 8\%]$ of μ_ξ, $\rho \in \{-0.45, 0, 0.45\}$, $\alpha_D \in \{0.7, 0.9\}$, $l \in \{0, \frac{1-\alpha_D}{8}, \frac{1-\alpha_D}{4}, \frac{1-\alpha_D}{2}\}$ and $k \in \{\frac{1}{1000}, \frac{1}{100}, \frac{1}{10}\}$.

3

Results and Insights

We identify that the overall resource network's flexibility plays an important role in the interplay between financial flexibility at any stage and flexible technology. Because the operating budget can be allocated between the two products in response to the demand realizations, the operating budget can be interpreted as a flexible resource that is used in conjunction with the capacity investment. In a budget-constrained environment, the technology choice is determined by comparing a flexible system (flexible capacity and a flexible operating budget) with a partially-flexible system (dedicated capacities and flexible operating budget). In the absence of budget constraints, because the operating budget is not constraining, this comparison is between a flexible system (flexible capacity) and a non-flexible system (dedicated capacities). In other words, the flexibility of the operating budget brings dedicated technology closer to flexible technology in terms of the overall resource network's flexibility. We show that to what extent this flexibility is beneficial with dedicated technology, i.e., the pooling value of the operating budget with dedicated technology, is an important driver of the technology choice. In discussing our managerial insights, we say financial flexibility (in the capacity investment or production stage) and flexible technology are complements when higher financial flexibility favors adoption of flexible technology, and they are substitutes otherwise.

Impact of lower financial flexibility in the capacity investment stage. Intuitively, a tighter capital budget has a negative impact on profitability under either technology; however, it is an open question which technology is less negatively affected. With identical capacity intensities, we find that because dedicated technology has a lower total capacity investment cost, this technology should be adopted for a larger unit investment cost range, and thus, is the best response to the tightening of the capital budget. The general insight is that flexible technology and financial flexibility in the capacity investment stage are complements in this case. When flexible technology has a larger capacity intensity, the dominant regime is the same unless the capital budget is severely constraining and the financial flexibility in the production stage is moderate. In this case, the operating budget considerations become critical: Because the total capacity investment level is less sensitive to changes in financial flexibility in the production stage with dedicated technology, this technology has a higher total capacity investment cost. Therefore, flexible technology should be adopted for a larger unit investment cost range, and thus, is the best response to the tightening of the capital budget.

Impact of lower financial flexibility in the production stage. Lower financial flexibility in this stage is captured by a lower likelihood that the firm is able to find an operating budget that is sufficient to fully cover the operating costs for any capacity level, i.e., a lower β. Intuitively, a lower β has a negative impact on profitability under either technology; however, it is an open question which technology is less negatively affected. With identical capacity intensities, we find that the dominant regime is one where dedicated technology should be adopted for a larger unit investment cost range, and thus, is the best response to lower financial flexibility in the production stage. This finding is reversed when the financial flexibility is sufficiently low. These results are driven by the impact of financial flexibility in the production stage on the pooling value of the operating budget with dedicated technology: We establish that lower financial flexibility increases this pooling value unless the financial flexibility is sufficiently low. When flexible technology has a higher capacity intensity, the total production cost is lower with this technology, and thus, all else equal, this technology is less negatively impacted by lower financial flexibility in the production stage. When the capacity intensity of flexible technology is sufficiently large, this effect outweighs the increasing pooling value of the operating budget with dedicated technology: The dominant regime is one where flexible technology should be adopted for a larger unit investment cost range, and thus, is the best response to lower financial flexibility. Our results show that when flexible technology has larger capacity intensity, financial flexibility in the production stage and flexible technology are substitutes unless the capital budget is moderately constraining and the financial flexibility in the production stage is also moderate; otherwise they are complements.

The capacity intensity of a technology is affected by its automation level. When the highly automated technology requires a higher capacity cost but a lower labor cost than the less automated technology, the former has a higher capacity intensity. Thus, our results underline the importance of considering financial flexibility level when deciding the automation level of the production technology. The capacity intensity of a technology may also be affected by the location of the production plant. This is because labor costs, which can constitute a big part of production costs, may vary with respect to the plant location. For example, in 2005, BMW located its flexible production plant in Germany, where labor costs are very high compared with the other alternative plant locations in Eastern Europe (Edmondson, 2005). If BMW had chosen one of the other alternative locations, the capacity intensity of the flexible technology would have been lower. Therefore, the impact of lower financial flexibility (in any stage), which have gained importance since the Eurozone financial crisis, may have a different impact in each location, and should potentially lead to a different technology choice. Therefore, our results underline the need for firms to take a holistic view of the technology adoption in their plant network and to manage facility location and technology adoption together in the presence of financial constraints.

The financial flexibility of a business unit is closely linked to the product portfolio of the parent company. For example, business units producing a premium product are more likely to be allocated sufficient budgets to cover their operating costs, thus, they have a higher financial flexibility in the production stage. The financial flexibility of the business unit may also vary based on the diversification level of the product portfolio of the parent company. If the products are highly diversified, one may argue that their production costs are not strongly positively correlated. In this case, if the focal business unit requires additional financing due to an unexpected increase in the operating cost, the headquarters can provide additional financing by reallocating funds from the other business units. Because the financial flexibility is critical in the optimal technology choice, there is value in coordinating the technology investment and the product portfolio decision.

4

Future research

Relaxing the assumptions made on the modeling of the budget constraints gives rise to a number of interesting areas for future research. First, there is our assumption of two-point characterization of the operating budget uncertainty. Second, we assume exogenous capital and operating budgets for the business unit that are allocated by the parent company. It will be interesting to study this allocation decision in an equilibrium setting. Another future research direction is to investigate the impact of demand uncertainty on the optimal technology choice. In the presence of full financial flexibility, i.e., in the absence of financial constraints, the extant literature demonstrates that a higher demand variability or a lower demand correlation benefits the flexible technology due to its increasing capacity pooling value. In the presence of financial inflexibility, the same result would continue to hold when the operating budget is product-specific with the dedicated technology. However, when the operating budget can be allocated among the products at any ratio, this budget also has a pooling value. Therefore, we expect that dedicated technology also benefits from a higher demand variability or a lower demand correlation. Which one of the two pooling values would increase more is an open question.

References

Babich, V. 2010. "Independence of Capacity Ordering and Financial Subsidies to Risky Suppliers". *Manufacturing & Service Operations Management*. 12(4): 583–607. DOI: 10.1287/msom.1090.0284. eprint: http://pubsonline.informs.org/doi/pdf/10.1287/msom.1090.0284.

Babich, V. and M. J. Sobel. 2004. "Pre-IPO Operational and Financial Decisions". *Management Science*. 50(7): 935–948. DOI: 10.1287/mnsc.1040.0252. eprint: https://doi.org/10.1287/mnsc.1040.0252. URL: https://doi.org/10.1287/mnsc.1040.0252.

Boyabatlı, O., T. Leng, and L. B. Toktay. 2016. "The Impact of Budget Constraints on Flexible vs. Dedicated Technology Choice". *Management Science*. 62(1): 225–244. DOI: 10.1287/mnsc.2014.2093. eprint: https://doi.org/10.1287/mnsc.2014.2093. URL: https://doi.org/10.1287/mnsc.2014.2093.

Boyabatlı, O. and L. B. Toktay. 2011. "Stochastic Capacity Investment and Flexible vs. Dedicated Technology Choice in Imperfect Capital Markets". *Management Science*. 57(12): 2163–2179. DOI: 10.1287/mnsc.1110.1395. eprint: https://doi.org/10.1287/mnsc.1110.1395. URL: https://doi.org/10.1287/mnsc.1110.1395.

Bream, R. and P. Marsh. 2008. "Steel to plastics price rises start to hurt industry". English. Copyright - (Copyright Financial Times Ltd. 2008. All rights reserved.; People - Marsh, Peter; Last updated - 2010-06-12. URL: http://libproxy.smu.edu.sg/login?url=https://search-proquest-com.libproxy.smu.edu.sg/docview/250068932?accountid=28662.

Buzacott, J. A. and R. Q. Zhang. 2004. "Inventory Management with Asset-Based Financing". *Management Science*. 50(9): 1274–1292. DOI: 10.1287/mnsc.1040.0278. eprint: https://doi.org/10.1287/mnsc.1040.0278. URL: https://doi.org/10.1287/mnsc.1040.0278.

Chava, S. and A. Purnanandam. 2011. "The effect of banking crisis on bank-dependent borrowers". *Journal of Financial Economics*. 99(1): 116–135. ISSN: 0304-405X. DOI: https://doi.org/10.1016/j.jfineco.2010.08.006. URL: http://www.sciencedirect.com/science/article/pii/S0304405X10001820.

Chod, J. and J. Zhou. 2014. "Resource Flexibility and Capital Structure". *Management Science*. 60(3): 708–729. DOI: 10.1287/mnsc.2013.1777. eprint: https://doi.org/10.1287/mnsc.2013.1777. URL: https://doi.org/10.1287/mnsc.2013.1777.

Data-Monitor. 2009. "Automobiles Industry Profile: Global". URL: www.datamonitor.com.

Edmondson, G. 2005. "BMW keeps the home fires burning". *Business Week*. May.

Eynan, A. and L. Dong. 2012. "Design of Flexible Multi-Stage Processes". English. *Production and Operations Management*. 21(1): 194–X. Copyright - Copyright Blackwell Publishers Inc. Jan/Feb 2012; Document feature - Equations; Graphs; ; Last updated - 2012-02-28; CODEN - POMAEN. URL: http://libproxy.smu.edu.sg/login?url=https://search-proquest-com.libproxy.smu.edu.sg/docview/922718280?accountid=28662.

Matson, J. 2009. “Cash is King: Improving Working Capital”. English. *Supply Chain Management Review*. 13(3): 28. Copyright - Copyright Reed Business Information, a division of Reed Elsevier, Inc. Apr 2009; Last updated - 2012-01-29. URL: http://libproxy.smu.edu.sg/login?url=https://search-proquest-com.libproxy.smu.edu.sg/docview/221134568?accountid=28662.

Modigliani, F. and M. H. Miller. 1958. “The Cost of Capital, Corporation Finance and the Theory of Investment”. *The American Economic Review*. 48(3): 261–297. ISSN: 00028282. URL: http://www.jstor.org/stable/1809766.

Pimlott, D. 2009. “Surveys highlighting gathering speed of decline”. *Financial Times*. Feb.

Scharfstein, D. S. and J. C. Stein. 2000. “The Dark Side of Internal Capital Markets: Divisional Rent-Seeking and Inefficient Investment”. *The Journal of Finance*. 55(6): 2537–2564. ISSN: 1540-6261. DOI: 10.1111/0022-1082.00299. URL: http://dx.doi.org/10.1111/0022-1082.00299.

Stein, J. C. 1997. “Internal Capital Markets and the Competition for Corporate Resources”. *The Journal of Finance*. 52(1): 111–133. ISSN: 1540-6261. DOI: 10.1111/j.1540-6261.1997.tb03810.x. URL: http://dx.doi.org/10.1111/j.1540-6261.1997.tb03810.x.

Stein, J. C. 2001. “Agency, Information and Corporate Investment”. English. Copyright - Copyright National Bureau of Economic Research, Inc. Jun 2001; Last updated - 2015-12-18. URL: http://libproxy.smu.edu.sg/login?url=https://search-proquest-com.libproxy.smu.edu.sg/docview/1689547543?accountid=28662.

Van Mieghem Jan, A. 2003. “Capacity Management, Investment, and Hedging: Review and Recent Developments”. English. *Manufacturing & Service Operations Management*. 5(4): 269–302. Copyright - Copyright Institute for Operations Research and the Management Sciences Fall 2003; Document feature - equations; tables; references; graphs; Last updated - 2010-06-06. URL: http://libproxy.smu.edu.sg/login?url=https://search-proquest-com.libproxy.smu.edu.sg/docview/200598647?accountid=28662.

Yang, S. A. and J. R. Birge. 2017. “Trade credit, risk sharing, and inventory financing portfolios”. *Management Science*.

Yang, S. A., J. R. Birge, and R. P. Parker. 2015. “The Supply Chain Effects of Bankruptcy”. *Management Science*. 61(10): 2320–2338. DOI: 10.1287/mnsc.2014.2079. eprint: https://doi.org/10.1287/mnsc.2014.2079. URL: https://doi.org/10.1287/mnsc.2014.2079.