European Journal of Operational Research 254 (2016) 1074–1082

Contents lists available at ScienceDirect

European Journal of Operational Research

journal homepage: www.elsevier.com/locate/ejor

Interfaces with Other Disciplines

# Pareto improvement and joint cash management optimisation for banks and cash-in-transit firms

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ARTICLE INFO

*Article history:*
Received 25 September 2015
Accepted 23 April 2016
Available online 11 May 2016

*Keywords:*
OR in banking
Cash-management
Group decisions and negotiations
Supply chain management

ABSTRACT

Improving the ATM cash management techniques of banks has already received significant attention in the literature as a separate optimisation problem for banks and the independent firms that supply cash to automated teller machines. This article concentrates instead on a further possibility of cost reduction: optimising the cash management problem as one single problem. Doing so, contractual prices between banks and the cash in transit firms can be in general modified allowing for further cost reduction relative to individual optimisations. In order to show the pertinence of this procedure, we have determined possible Pareto-improvement re-contracting schemes based on a Baumol-type cash demand forecast for a Hungarian commercial bank resulting in substantial cost reduction.



## 1. Introduction

Due to dramatic changes in interest rates and in the availability of funds, especially during crisis, cash management of banks received much attention. This focus on cash management was partly motivated by the cost effective functioning—though cash management costs are relatively small compared to the overall banking costs—and partly by better assuring liquidity in periods of shortage in liquidity.

The proper cash management assures the optimal quantity of cash at the right place and time. Accordingly, the focus in the literature on cash management of banks is to improve the stochastic cash demand forecasts. Cash management policies can be built upon these forecasts, for example by the help of linear (stochastic multistage) programming. In brief, the basic idea of cost reduction is optimisation under given constraints in various environments. In concrete terms, the cash management of ATMs is equivalent to the problem of finding the optimal amount of cash and the optimal number of transports at given interest rate (opportunity cost of holding cash) and given transportation fee. The transportation fee comprises in general two components: a fix fee per transport and a variable fee on the amount handled (replenished or emptied). This logic allows thus for cost reduction by the help of better prediction and optimisation techniques.

As far as we know, none of the contributions to the cash management literature on ATMs has investigated another potential cost gain which is independent of the prediction and optimisation techniques. Namely, in general it is possible to reduce the overall cash management costs by holding the overall transportation costs and the interest rate constant. For this eventuality, the composition of the fix and variable parts of the transportation fee should induce an appropriate variation of the amount and the number of transported cash; the gain comes from the reduction of the total opportunity cost of holding cash (interest). The problem is not just finding the optimal cash management scheme for given prices but offer a new Pareto improvement pricing scheme which makes the bank strictly better off.

In this paper we use the simple Baumol technic to predict the cash demand though better prediction methods are available. This is because our purpose is to hold the model as simple as possible in order to insure that the bank management understands and accepts it. The model is applied for a Hungarian commercial bank's cash logistics of withdrawal ATMs replenished by an independent firm from a central hub by way of replacing unopened cash cassettes. While the Baumol prediction oversimplifies some real world facts, the policy built upon this prediction method can still significantly reduces cash management cost in our empirical case.

Clearly, the re-contracting policy of the bank with the cash in transit firm following the Pareto improvement logic applies in any case when the cash management scheme is optimised without

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http://dx.doi.org/10.1016/j.ejor.2016.04.045
0377-2217/

taking into consideration the concrete cost structure of the transportation; especially, if the cash transportation is assured by an independent firm. The point is that independent optimisation (CIT optimises independently of the bank) cannot produce better result than joint optimisation. Also, the re- contracting policy suggested in this paper is not dependent on the optimisation and prediction technique. In this regard, any limitations coming from the Baumol technic are irrelevant.

This article determines just the Pareto improvement re-contracting payment schemes between banks and the cash supplying firms, a precondition of strategic behaviour for the implementation of enhanced payment schemes. The implementation of the possible ensuing contracts between the bank and the independent firm is outside the scope of this article; a straightforward framework for handling the implementation problem is to define an appropriate bargaining game.

Following this introduction, Section 2 presents the relevant literature. Section 3 constructs a Baumol-type model for predicting the cash demand and examines four scenarios based on the amount of the unloaded cash $y_{un}$ and the independent firm's (henceforth the Firm) cost CT. Section 4 presents the Hungarian commercial bank (henceforth the Bank ). Afterwards, this theoretical model is applied on the Bank's representative ATM and an augmented simulation model on its overall ATM network—the positive test outcomes suggest three pricing schemes. Finally, Section 5 concludes the article by summarising the research findings and suggesting possible avenues for policy implications and further methodological amendment.

## 2. Relevant literature on cash management

The cash management literature starts with the pioneering contribution on the transactions demand for money by Baumol (1952) and Tobin (1956). The basic model investigates the optimal size of cash holdings in a deterministic setting—where the choice is between cash and an interest-bearing asset, with strictly positive trade-off costs between the two assets. Integrating other (transaction) cost elements and stochastic money flows is a straightforward extension of this basic model (Miller and Orr (1966), Heyman (1973)). To this end, Eppen and Fama (1968) used linear programming and assumed stationary net cash flows to satisfy the Markov process. Elton and Gruber (1974) used dynamic programming. Following these early works a great number of authors contributed to the cash management literature (the list is non-exhaustive): Hinderer and Waldmann (2001) generalised the so called (u,U,D,d) role for a wider environment, Cardo (2009) conceived the cash management problem as a stochastic problem and solved it with (mixed) integer linear programming. Bar-Ilan, Perry, and Stadje (2004) used a generalised impulse control model. Yao, Chen, and Lu (2006) and Arora and Saini (2014) used the fuzzy integral method. Simutis, Dilijonas, Bastina, Friman, and Drobinov (2007) constructed an artificial neural network to forecast the daily cash demands for ATMs and estimate the optimal ATM cash loads—Venkatesh, Ravi, Prinzie, and Van Den Poel (2014) used neural networks too, but clustered ATMs preliminarily. Armenise, Birtolo, Sangianantoni, and Troiano (2010) used a specific genetic algorithm. Teddy and Ng (2011) forecasted the cashdemands with the help of cerebellar associative memory network, Ekinci, Lu, and Duman (2015) used group-demand forecasts. Baker, Jayaraman, and Ashley (2013) dropped the assumption of normally distributed errors to improve the cash demand forecast. Dilijonas, Sakalauskas, Kriksciuniene, and Simutis (2009) combined optimisation with ATM management.

In summary, much of the literature on cash management is concerned with cash supply optimisation within a given cash allocation scheme. According to Cabello (2013, p. 334), most analyses 'in the financial literature assume the standard allocation models of cash from central hubs to branches as given'. However, Pokutta and Schmaltz (2011) showed that choosing the appropriate liquidity hub scheme results in significant economies.

Batlin and Hinko (1982) furthered the literature by replacing the standard allocation framework with a game theoretical framework and by analysing the interaction between cash flow acceleration and liquidity. This novel approach also shed light on an important lacuna of the standard allocation framework—cash management costs may indeed be reduced by enhanced cash flow predictions, but also by enhanced contractual pricing between banks and the firms that supply cash to bank branches and ATMs. Consequently, this article builds on Baumol (1952) and Tobin (1956) by suggesting a Baumol-type model and advocating further economies within the standard framework from enhanced contractual pricing.

Naturally, cash optimisation may be analysed from perspectives different from that adopted in this article. Blackman, Holland, and Westcott (2013) and Popa (2013) did indeed do so, from the perspective of global financial supply chain strategies, as did de Haan and van den (2013), from the perspective of regulatory implications (see also Basel Committee on Banking Supervision (2013) and Burcea, Bălău, Bâldan, Avrămescu, and Ungureanu (2013) on liquidity management). Also, in a reversal of emphasis, Snellmana and Virenb (2009) examined how markets and ATM network structures affect payment choices; Bátiz-Lazo (2009) examined ATM network structures in the UK; and Opasanon and Lertsanti (2013) examined the cost efficiencies of companies that provide logistics services for banks. However, such perspectives are outside the scope of this article.

Finally some articles are aiming at modelling the cost structure related to the cash management problem. Ou, Hung, Yen, and Liu (2009) investigate the effect of ATM deployment on cost efficiency. Stavins (2000) analyses the use of non-customer ATM fees, while Bjø rndal, Hamers, and Koster (2004) investigate the ATM fees with the help of cooperative game theory.

## 3. Methodology and discussion

The ATM cash management literature is mainly concerned with developing better cash demand predictions and better replenishment policy by the help of optimisation programs. This article concentrates instead on the further possibility of cost reduction—optimising the ATM cash management problem as one single problem. Therefore, we use a simple Baumol-type model to forecast the cash demand. The limitations of this simple model are secondary for now, because the possible economies are not based on better predictions or better optimisation but on joint optimisation of the ATM cash management problem instead of the optimisation of two separate programs of banks and cash in transit firms.

The Baumol type model advanced here below is applied for withdrawal ATMs; for deposit ATMs see Appendix A. The model divides time into periods—days—and uses a number of symbols:

- $a$ 1 + value added tax (VAT),
- $C_T$ an independent firm's total daily cost for a specific ATM,
- $e$ an independent firm's initial total daily earning for a specific ATM,
- $E$ an independent firm's total daily earning for a specific ATM,
- $E^*$ an independent firm's optimal total daily earning for a specific ATM,
- $f$ the daily turnover of a specific ATM (defined as the total successful withdrawal from that ATM),
- $k$ an independent firm's journey fee for a specific ATM (defined as the price the independent firm charges for a specific number of transports to that ATM),