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The future of branch cash holdings management is here: New Markov chains

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ABSTRACT

Liquidity management is one of the main concerns of the banking sector since it provides control in key areas such as treasury management, working capital financing and business valuation. Under the assumption that branch efficiency makes a fundamental contribution towards the effective performance of the global banking institution, this paper provides a new methodology (Markov chains by blocks) in order to achieve knowledge on the branch cash holdings: conditions which ensure optimal cash holdings, recurring properties which help to better predict cash holdings shifts and the study of the branch cash holdings steady-states using Ergodic Theory. These findings will let bank managers know *the time validity of the current cash holdings*. This is a crucial advantage to ensure efficient cash management: while helping keep banking institutions on sound financial footing by guaranteeing the compulsory-by-law safety cushion, it also allows bank managers to make sound decisions upon fund investments.

This incipient mathematical framework, based on the re-definition of classical theory on Markov chains, provides an alternative standpoint which may also apply to those dynamical systems which can be categorized into groups of similar features.

1. Introduction and literature review

Corporate/bank cash holdings have always played a crucial role in the development of firms and financial institutions: without cash, they could both become insolvent and at risk of bankruptcy. Thus, efficient cash administration has traditionally focused the attention of managers and shareholders, especially during periods of uncertain market and credit conditions. In this regard, an accurate cash balance *forecast* is critical for successful management while also serving other strategic purposes such as controlling subsidiary groups.

The banking industry has been in search of managerial measures to improve the control of its liquid resources in order to increase efficiency. While efficiency on all fronts (including cash management) has become a primary objective for banking industry over the last decade, there is a body of research which argues that branches have a role to play in helping to improve global bank institution performance. This was firstly suggested in Berger, Leusner, and Mingo (1997), whose authors stressed the importance of the efficiency of branches as making a fundamental contribution towards the effective performance of the global banking institution. Moreover, the authors of Berger et al. (1997) called attention to the fact that branch efficiency literature is much less complete than banking efficiency literature. As a matter of fact, specific literature to design techniques to improve branching performance *as far as cash management is concerned* is quite short[1] apart from those papers which focus on regulatory measures to control under-performing branches. The present paper attempts to help to fill this gap by proposing specific conditions to improve cash (forecasting) management at branch level.

In the area of management of corporate cash holdings, there have been a long series of attempts to determine the optimal investments that organizations should make in cash. Models of cash management or money demand can be categorized into two types: those with demand by households, pioneered by the Baumol–Tobin model, (Baumol, 1952) and continued by Frenkel and Jovanovic (1980), Bar-Illan (1990) and Chang (1999) and those which concern cash management by firms, pioneered by the paper of Miller and Orr (1966). Firms differ from households in that firms have daily cash inflow as well as daily expenditures. Also the size of financial transactions differentiates firms from households, as large and instantaneous transactions are more likely. In terms

[1] "Short" unless the strand of research focused on improving the performance of automatic teller machines, ATMs, would be considered as part of the literature to improve branch cash management.

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of their mathematical structures, the first describes the money stock between controls by means of Brownian motion with drift whereas Miller and Orr formulated a model under which an organization's cash flow evolves in terms of a stationary random walk. Later proposals feature unified analysis of cash management by combining Brownian motion and compound Poisson processes, as in Bar-Illan, Perry, and Stadje (2004). Other authors classify cash management models according to their mathematical fundamentals. Following Melo and Bilich (2011), these models can be grouped into Inventory Theory models (now both Baumol–Tobin and Miller–Orr belong to the same category), those developed with Linear Programming and those which are based upon Dynamic Programming.

Further papers incorporate stochastic techniques in their patterns of cash management: Baccarin (2009) considers the optimal control of a multidimensional cash management system where the cash balances fluctuate as a homogeneous diffusion process in $\mathbb{R}^n$. Cyert, Davidson, and Thompson (1962) pioneered research using Markov chains for estimating the allowance of doubtful accounts while Hinderer and Waldmann (2001) analyzed a cash management system in which the distribution of the cash flow depends on a randomly varying environment. Ferstl and Weissensteiner (2008) considers a cash management problem by using a multistage stochastic linear program (SLP). In Higson, Yoshikatsu, and Tippet (2010), the authors model the evolution of cash in terms of a square root process modified with a Brownian motion in such a way that the statistical properties of the cash flow process depend on the cash holdings. This functional relationship between cash holdings and cash flow process by means of Hamilton–Jacobi–Bellman equations and other elements of optimal control theory is the core qualitative finding of Anderson and Caverhill (2012). In Bensoussan, Chutani, and Sethi (2009) the author uses a stochastic maximum principle to obtain an optimal transaction policy. In Sato and Suzuki (2011), a cash management model is built around Brownian motions and Poissson processes while Song, Ching, Siu, and Yiu (2013) discuss a cash management model for firms based on a stochastic volatility (SV) model. And more recently, Tangsucheeva and Prabhu (2014), where a cash flow forecasting model is developed in terms of Markov chains and bayesian models.

However, there is little current literature about this subject for the *banking industry*, whose specific characteristics differ from firms and other economic organizations. While credit lines are freely available for the banking industry, the private sector must apply for external financing within the framework of those credit channels that are accessible to it. Actually, the relationship between cash holdings and credit risk is present in most former models of cash management: see Acharya, Davydenko, and Strebulaev (2012), where a dynamic continuous-time model allows for a description of the correlation between credit spreads and cash reserves. Or Anderson and Caverhill (2012), where the authors develop a model of optimal policy toward holding the liquid assets of a firm which faces external financing. Banks differ from firms also in the peculiar dynamics of their cash flow processes. Assorted entries of cash are specific to banks: at the branch level, as daily expected and unexpected deposits and withdrawals, similar to ATM dynamics, while at the aggregate level, large/huge transactions take place as a consequence of movements of money amongst bank entities. Distinct regulation packages are also applied in order to control banking industry versus private sector.

The ultimate aim as far as liquidity management is concerned is to find the optimal level of cash since it would help banking institutions facing short-term obligations at the aggregate and branch level, while minimizing the risk of bankruptcy in long-term projections. This "optimal" level of cash may be also read as "enough" cash. However, finance literature has given very little *precise* guidance on this question: how much money is enough for a banking institution?

Common knowledge suggests that banks that have larger liquid assets should be safer. However, when banking firms keep liquid resources in cash, they renounce a part of their profitability, incurring the opportunity costs of not investing in other alternatives which do generate profits. Thus, the intuition recommends that a balance between minimizing costs and maximizing profits should be kept in order to ensure high levels of efficiency. But, how do the banks identify the right proportion to be held?

This paper attempts to fill this gap by providing answers to the above questions in the context of bank branches. Stated briefly, the contributions of this paper are twofold: a deep study of the branch cash holdings from a dynamic point of view (first contribution) through an approach based on new stochastic financial analytics that we have developed in this paper (second contribution). Actually, this paper provides a new methodology (Markov chains by blocks) in order to achieve knowledge on the branch cash holdings with proposals to be approached from a variety of perspectives: i)conditions which ensure optimal cash holdings, ii)recurring properties of the branch cash holdings derived from the natural cyclicity exhibited in the branch cash management practice which help to better predict their shifts and iii) the study of the branch cash holdings steady-states using Ergodic Theory, (Braido, 2013), which let bank managers know *the time validity of the current cash holdings*. In general, we find policies on holding optimal levels of liquid assets aimed at being useful for both bank and branch managers. These conditions are crucial to ensure efficient cash management: while helping keep banking institutions on sound financial footing by guaranteeing the compulsory-by-law safety cushion, it also allows bank managers to make sound decisions upon fund investments. As far as the author knows, this is the first time in the literature that such an analysis on cash holdings at the branch level has been carried out from a dynamic point of view.

This incipient mathematical framework, based on the redefinition of classical theory on Markov chains, provides an alternative standpoint which may also apply to those dynamical systems which can be categorized into groups of similar features.

The remainder of the paper is organized as follows. In Section 2, an overview of *clustering* methods (*identification of similarities*) is presented since the cyclicity that exists in the branch cash management practices (which is at the heart of our study) relies on the idea of grouping the weeks into *blocks of weeks with similar features*. Section 3 presents the general framework of the liquids funds of a branch. Section 4 is aimed at setting conditions to ensure optimal cash holdings. Recurring properties on branch cash holdings are presented in Section 5, while time validity on cash holdings is analyzed in depth in Section 6. Section 7 contains a numerical example, based on real data for a branched-bank. Finally, Section 8 concludes the paper.

2. Clustering: related approaches

As mentioned before, one of the key insights of the paper is the natural cyclicity exhibited in the branch cash management practice: in detail, that refers to the usual branch managers' partition of the year into *blocks of weeks with similar features* in order to require the same amount of case for all weeks inside the same block.[2] Around this idea, a new methodology – called Markov chains by blocks- is developed in this paper: specifically, the whole temporal sequence of branch cash holdings, which is previously shown to be a Markov chain, is partitioned into blocks such that this partition is well correlated with the partition of the year by

[2] For instance, a block of weeks is "first weeks of each month".