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Smooth-adjustment econometrics and inventory-theoretic money management

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ABSTRACT

A growing number of empirical papers use Miller–Orr (S, s) money management as economic motivation for application of non-linear smooth-adjustment models. This paper shows such models are not implied by the Miller–Orr economy. Instead, the Miller–Orr economy implies non-standard smooth-adjustment, as derived in the neglected (and misinterpreted) work of [Milbourne et al. \(1983\)](#). Remarkably, this function includes a varying weight on the lagged dependent variable, capturing static (not dynamic) effects. Interpretations of these apparent dynamics are presented, some of which may be useful in non-monetary (S, s) contexts. Results imply a new agenda for applied smooth-adjustment modeling of money.

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0. Introduction

Non-linear smooth-adjustment models as developed by [Terasvirta \(1994\)](#) have been applied to monetary data in a growing number of empirical studies. Where authors have offered motivation from monetary theory for these non-linear methods they have always made reference to target-threshold (or trigger-target, or S, s) money management rules based upon inventory theory, with most referring to the [Miller–Orr \(1966\)](#) variant. This is natural, as Miller–Orr style money management induces complex behavior, and smooth-adjustment models employ very flexible non-linear functional forms.

The Miller–Orr monetary model is cited as underlying motivation for smooth-adjustment econometrics applied to Italian data in [Sarno \(1999\)](#), for Taiwan in [Huang et al. \(2001\)](#), to Spanish data in [Ordóñez \(2003\)](#), and for US data in [Sarno et al. \(2003\)](#). The most detailed argument for this economic rationale is provided in [Sarno's \(1999\)](#) paper and again in [Sarno et al. \(2003\)](#). Other papers using Miller–Orr as economic motivation for smooth-adjustment either refer to or reproduce elements of their argument. These more recent papers include [Chen and Wu \(2005\)](#) who investigate both US and UK data [Lee et al. \(2007\)](#) for G-7 data, US data again in [Haug and Tam \(2007\)](#), and then data for Taiwan in [Wu and Hu \(2007\)](#) and again in [Lee and Chang \(2008\)](#).¹

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E-mail address: clinton_greene@umsl.edu¹ Via the SCOPUS data-base it was found that the works in this list of papers (claiming a Miller–Orr rationale) were in turn cited in eighteen other published papers, nine of these in 2007–2008. Among the eighteen, ten cite [Sarno \(1999\)](#) or [Sarno et al. \(2003\)](#).

The argument made for a tie between smooth-adjustment and the Miller–Orr economy is based upon the fact that under the Miller–Orr rule (and under inventory-theoretic models in general) the individual agent allows the balance to wander as driven by random net receipts, and adjustment to a target level is triggered only if the balance breaches upper or lower bounds of some interval. It is taken as intuitively obvious that the larger the deviation of holdings from the long-run (or average, or equilibrium) value then the more likely it is that many accounts are close to breaching their trigger-points, soon to adjust towards the targets. Thus the deviation of holdings from their long-run levels should affect the speed of adjustment towards this long-run, with the speed of adjustment increasing with the size of the aggregate deviation. It is then noted that smooth-adjustment functions allow for just such a positive relationship between (on the one hand) deviations from equilibrium and (on the other hand) the speed of adjustment. On that basis these papers claim it is intuitively obvious that Miller–Orr money management must imply smooth-adjustment.²

This paper shows that some of this intuition is correct, but a Miller–Orr economy induces important complications not captured in the standard smooth-adjustment functional forms. Consistent with the applied literature, the Miller–Orr economy is non-linear, and in a Miller–Orr economy standard smooth-adjustment functions can improve on the fit of linear models. But not for the reasons described in this literature. This paper also shows the standard smooth-adjustment representations of the Miller–Orr economy are unstable (in a Miller–Orr economy) and so forecast poorly. This instability is not a function of time, so may not be detected when applying standard stability tests. Anticipating the dimension along which this instability lies and specifying a stable non-linear function requires considerations additional to those discussed in this monetary smooth-adjustment literature.

In clarifying the issue it will be useful to compare the smooth-adjustment intuitions to some prior results neglected in the literature. *Milbourne et al. (1983, hereafter MB&W)* presented rigorous results on the form of aggregate non-linearity implied by Miller–Orr money management. But their results are not incorporated into any of these published papers applying smooth-adjustment econometrics.³ And their results have generally been neglected. The correct non-linear model derived by MB&W is a non-standard smooth-adjustment model with a static transition variable. The use of a static rather than a dynamic transition variable sets the correct model apart from the standard smooth-adjustment approach.

The fact that rigorous results for the non-linear nature of the Miller–Orr economy (derived by MB&W) have been largely ignored for a quarter-century is a puzzle in itself worth addressing. In my view there are two legitimate reasons for the neglect. First, the discussion in MB&W is very brief and does not provide a helpful description of the nature of their mathematical results. Second, their most precise results are buried among other loose approximations adopted for empirical application, necessitated by the limited computing power available at the time. Given these handicaps, it is not surprising that non-linear modeling of (S, s) economies has been little affected by their work.

In response to these difficulties, I present descriptions and intuitive heuristics useful for understanding the work of MB&W. Since (S, s) models have application not only in inventory management but also in some (New-Keynesian) price-adjustment modeling, some of the interpretation presented in this paper will be more broadly useful. So along the way I comment on which results here are likely to hold in other contexts and which characteristics are unique to money.

The paper proceeds in six steps. Section 1 discusses how a Miller–Orr economy implies (in the aggregate context) a model with the structure of partial-adjustment (or restricted error-correction), but with weights or coefficients which vary. In this initial discussion it will become apparent that the probability of portfolio adjustment does matter for coefficient values. Hence an aspect of the motivation for application of smooth-adjustment models to money data adopted in the applied literature is indeed correct.

In Section 2 simulation methods are used to investigate how well standard smooth-adjustment and related forms can model this varying probability as posited in the monetary smooth-adjustment literature, namely that this probability is a function of the difference between actual and expected money holdings. It turns out that such functional forms do no better than assuming a constant probability. This means that if smooth-adjustment models perform well empirically, then this is not due to this aspect of the story told in the literature.

The difficulty with the story is due to the fact that under aggregation money holdings can be larger than average without individual holdings lying closer than usual to the upper boundary of the (S, s) interval. To support intuition for the simulation results I provide a counter-example which can easily be extended to a continuum of variations. This result is the most likely to carry over into other non-monetary contexts.

In Section 3 I turn to the derivations of MB&W, showing that although their results can be seen as implying a highly modified smooth-adjustment model, the form is not the one used in the smooth-adjustment literature (to date) and the theoretical interpretation is quite different. In particular the standard smooth-adjustment model is telling a dynamic story. But although the non-linear MB&W model incorporates a lagged dependent variable, it is nonetheless a model of comparative statics.

That trigger-target (S, s) behaviors at the individual level can imply for an aggregated model that lagged money is important, but this lag is not capturing dynamic effects, is perhaps the key insight into the nature of a monetary (S, s) economy. Likewise non-linearity is generated in a comparative-statics context. Once one understands the static basis for

² Motivation from buffer-stock models is also mentioned. A buffer-stock is an inventory, and inventory optimization leads to (S, s) rules, so it is not clear that buffer-stock theory is distinct from Miller–Orr type thinking.

³ Although cited by *Sarno (1999)*, the actual results of MB&W are not discussed nor used.

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