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# Interest rate rules, endogenous cycles, and chaotic dynamics in open economies

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ABSTRACT

We present an extensive analysis of the consequences for global equilibrium determinacy in flexible-price open economies of implementing active interest rate rules, i.e., monetary rules where the nominal interest rate responds more than proportionally to inflation. We show that conditions under which these rules generate aggregate instability by inducing liquidity traps, endogenous cycles, and chaotic dynamics depend on specific characteristics of *open* economies. In particular, rules that respond to expected future inflation are more prone to induce endogenous cyclical and chaotic dynamics the more open the economy to trade.



## 1. Introduction

In a recent paper, Bullard (2010) argues that the extremely low interest rates observed in the U.S. and in major developed economies after the financial crisis are consistent with the theoretical findings by Benhabib et al. (2001b). The latter shows how, because of the zero lower bound (ZLB) on the nominal interest rate, simple Taylor rules can induce a liquidity trap – a situation where the nominal interest rate drifts away from its target toward an unintended low steady state – even if the rule satisfies the celebrated Taylor principle by responding more than proportionally to inflation (an active rule).

The liquidity trap in Benhabib et al. (2001b) is an equilibrium that is entirely driven by people's self-fulfilling expectations. It is in fact the natural outcome from a *non-linear* analysis of the prototype micro-founded dynamic model that has become the workhorse for macroeconomic policy discussions. However, as Bullard (2010) points out, this outcome has surprisingly received scarce attention in the policy debate. Central banks often organize their discussions by looking at the impulse responses of *linearized* versions of the truly non-linear models. By doing so, they tend to rule out *a priori,* as a viable equilibrium, all the non-linear trajectories that move away from their targets, including liquidity traps.

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Benhabib et al. (2001b, 2002a) also show that a global rather than a local analysis unveils the existence of other Taylor-rule-induced rational expectations equilibria, such as endogenous limit cycles and chaotic dynamics.[1] This questions policy recommendations based on linearized models, since Taylor rules that ensure a unique local equilibrium may actually generate aggregate instability by inducing global cyclical fluctuations. The works by Benhabib et al., however, are based on *closed* economy models raising the question of whether similar results hold in the context of open economies. To this date, this still remains a valid question since most of the studies in open economies have been restricted exclusively to local analyses. De Fiore and Liu (2005), Llosa and Tuesta (2008), and Zanna (2003), for instance, pursue local analysis of Taylor rules in the context of a small open economy setup; while Benigno and Benigno (2008), Bullard and Singh (2008) and Leith and Wren-Lewis (2009), among others, present similar analyses in open economy models with more than one country.

The purpose of our paper is to assess how the existence of these self-fulfilling cyclical and chaotic fluctuations is affected by opening the economy to international trade in goods. We pursue a global non-linear equilibrium analysis of a traditional flexible-price small-open-economy model with traded and non-traded goods, where monetary policy takes the form of an active interest rate rule responding to expected future CPI inflation, i.e., forward-looking rules. By doing this, we bridge the gap between the *closed* economy literature on *global* analysis of Taylor rules and the *open* economy literature on *local* analysis of these rules.

Our main result is that forward-looking Taylor rules are more prone to induce endogenous cycles and chaos the more open the economy to trade. In contrast to the money-in-the-production-function (MIPF) setup of Benhabib et al. (2002a), we use a money-in-the-utility-function (MIUF) setup, whereby consumption and real money balances are non-separable in utility. As a result, these self-fulfilling complex fluctuations, whose existence depends on openness, can occur around either the target interest rate or the unintended low steady state, depending on whether consumption and money are Edgeworth substitutes or complements, respectively. Interestingly, the complements case allows for liquidity traps that converge non-monotonically to a limit cycle around the unintended steady state.

The global equilibrium dynamics in our model are driven by the interaction of an open-economy version of the Fisher equation and the non-linear Taylor rule. The modified Fisher equation is obtained from the combination of the uncovered interest parity condition and the definition of the consumer-price-index (CPI) inflation. In this modified equation, the dynamics of the ex ante real interest rate has to be consistent with future changes in the real exchange rate. Key to the existence of cycles and chaos is the elasticity of the real exchange rate to the policy interest rate. This elasticity is affected by the complementarity/substitutability between consumption and money and, more importantly for our purposes, by the degree of trade openness.

Relative to the works on global analysis in closed economies, we find that trade openness significantly enlarges the risk aversion parameter range under which forward-looking rules induce cycles and chaos. As in Benhabib et al. (2002a), the presence of a ZLB on nominal interest rates is a *necessary* condition for the existence of cyclical fluctuations. However, while these complex dynamics coexist in a MIUF closed economy model for a very *restricted* range of values of the risk aversion parameter, the same dynamics may occur for a much *wider* range of this parameter, as long as the economy is sufficiently open. By enlarging this range, openness plays a key qualitative role in determining the global determinacy properties of Taylor rules.

From a policy-making point of view, our results suggest that to avoid destabilizing endogenous cycles and chaos in *open* economies, the design of interest rate rules should take into account not only the interest response coefficient to inflation, but also specific structural characteristics, such as the degrees of openness. This complements the results of the aforementioned open economy literature on local analysis with one important caveat: as we show below, and in line with Benhabib et al. (2001b, 2002a), policy prescriptions that are derived from local analyses to ensure macroeconomic stability in an open economy can still lead to cycles and chaos (global indeterminacy), where the extent of disagreement between the local and global analyses depends on the degree of openness.

The remainder of this paper is organized as follows. In Section 2, we present a flexible-price model with its main assumptions. We define the open economy equilibrium and derive some basic steady state results. In Section 3, we pursue local and global equilibrium analyses for an interest rate rule that responds to expected future CPI inflation, focusing on the role played by the degree of openness. Section 4 discusses the robustness of our main results under different extensions, including imperfect exchange rate pass-through, incomplete markets, alternative timings for the policy rule and money in utility, and alternative preferences and technologies. Finally, Section 5 concludes.

## 2. A flexible-price model

### 2.1. The household-firm unit

Consider a small open economy (SOE) populated by a large number of identical and infinitely lived household-firm units. Each unit derives utility from consumption ($c_t$), real money balances ($m_t^d$), and not working ($1-h_t^T-h_t^N$) according to

$$E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{\left[(c_t)^{\gamma}(m_t^d)^{1-\gamma}\right]^{1-\sigma}-1}{1-\sigma} + \psi(1-h_t^T-h_t^N) \right\} \tag{1}$$

[1] See also Alstadheim and Henderson (2006), Eusepi (2007), and Evans et al. (2008).