



The butterfly effect of small open economies

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ABSTRACT

The rational expectations equilibrium of a small open economy can be subject to indeterminacy if foreign monetary policy does not satisfy the Taylor principle. We study the implications of foreign induced indeterminacy in the two-country version of the sticky-price small open economy model. Our main finding is that ‘smallness’ is a property of the unique rational expectations equilibrium of the large economy, and not a general property of the small open economy model. If the *large* economy fails to anchor expectations, shocks to the small economy can affect the large one. This form of indeterminacy gives rise to a ‘butterfly effect’. Additional assumptions are required to preserve the ‘smallness’ of the small economy.

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The flapping of a single butterfly's wing today produces a tiny change in the state of the atmosphere. Over a period of time, what the atmosphere actually does diverges from what it would have done. So, in a month's time, a tornado that would have devastated the Indonesian coast doesn't happen. Or maybe one that wasn't going to happen, does. [p. 141, Stewart, 1990, Does God Play Dice? The Mathematics of Chaos]

1. Introduction

A general agreement in the modern literature on monetary economics is that monetary policy should obey the Taylor principle: that the nominal short-term rate of interest should rise eventually more than one-for-one with the rate of inflation. There is evidence that the successes of monetary policy over the past two decades, compared to the problems in the 1970s, can be explained by reference to the Taylor principle.¹ In most sticky-price models, this principle ensures that beliefs themselves do not turn into independent sources of fluctuations.

In these models, a central bank that fails to satisfy the Taylor principle is unable to ensure a unique rational expectations equilibrium (REE) for the economy.² Such monetary policies lead to indeterminacy of the equilibrium: an economy for which many different outcomes are possible given the same fundamental situation. This problem of

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¹ See for example Bernanke (2004), Clarida et al. (2000), Lubik and Schorfheide (2004), and Mankiw (2002).

² See Woodford (2003b) for a detailed description of the relationship between the Taylor principle and uniqueness of the REE. See also Benhabib et al. (2001) for an example of a model in which the Taylor principle is not necessary for determinacy of the equilibrium.

non-uniqueness has attracted considerable attention in the literature; numerous authors long noticed, studied, and reacted in various ways to the multiplicity of solution paths in rational expectations models.³

With a closed economy new Keynesian model, in which violations of the Taylor principle lead to multiple equilibria, Lubik and Schorfheide (2004) show that prior to 1979 passive monetary policy better accounts for the dynamics of inflation and output in the U.S. economy. To the extent that indeterminacy—in a closed economy—is the result of an improper policy, determinacy could easily be restored by changing policy settings appropriately. As emphasized by Bullard and Singh (2008), however, good monetary policy can be insufficient to ensure determinacy of the REE in an open economy. Thus, an open economy may be exposed to non-fundamental fluctuations that ‘originate abroad’.

In general, indeterminacy of the REE can manifest itself in two non-exclusive ways. Non-fundamental disturbances may become additional sources of business fluctuations and fundamental shocks may propagate differently. One of our goals is to study the implications of foreign induced indeterminacy for a small open economy. In particular, with a sticky-price small open economy model we address the following question. How does the small economy respond to non-fundamental disturbances? To the best of our knowledge, no study has examined the implications of foreign indeterminacy in a *small* open economy. There is literature studying specific conditions for determinacy and indeterminacy in open economy models.⁴ Our focus here is different. We study, with a sticky-price small open economy model, the dynamic behavior of the economy under ‘inherited’ indeterminacy.

Our main finding, however, is this: if the large economy fails to achieve a unique equilibrium, shocks to the small economy may affect the large one. In other words, ‘loose’ expectations abroad create a channel through which shocks that originate in the small economy influence the large economy. We call this channel the ‘butterfly effect’.⁵ In this way, the theory gives a structural interpretation of sunspot shocks to the large economy.

Another one of our goals is to examine methodological aspects of solving small open economy models under rational expectations. As we discuss at length below, the ‘butterfly effect’ can be viewed as a result of an implicit assumption: expectations (in the small and large economy) are formed rationally with access to *full* information. Only if the equilibrium of the large economy is unique, is the small economy truly ‘small’. Therefore, ‘smallness’ is a property of the unique REE of the large economy. It is not our goal here, however, to assess the empirical relevance of this mechanism.

The rest of the paper is structured as follows. Section 2 describes the model. Section 3 discusses indeterminacy. Section 4 presents our findings and Section 5 concludes.

2. Model

We use the two-country version of Galí and Monacelli (2005) sticky-price small open economy model, which most closely resembles that used by Clarida et al. (2001), to illustrate our findings.⁶ It is important, however, to keep in mind that the ‘butterfly effect’, as we discuss below, is a general feature of *any* model that satisfies the matrix partition structure of Eq. (20) below, and not a particular feature of this version of Galí and Monacelli (2005) model.

Instead of working through the details of the derivation, which are in Galí and Monacelli (2005), we present the key log-linear aggregate relations.

2.1. The large economy

Variables with a *star superscript* correspond to the large foreign economy,⁷ which can be described with a standard set of new Keynesian closed economy equations.⁸

Firms operate under monopolistic competition in the goods market and Calvo-price stickiness. Factor markets are competitive and goods are produced with a constant returns to scale technology. One can show that if prices are sticky as in Calvo (1983), the new Phillips curve in the large economy takes the form

$$\pi_t^* = \beta E_t \pi_{t+1}^* + \kappa y_t^* + \nu_{\pi,t}^* \quad (1)$$

where π_t^* stands for the foreign inflation rate, y_t^* is the foreign output gap, $\nu_{\pi,t}^*$ is a foreign cost-push shock; the parameter κ is strictly positive and captures the degree of price rigidities; the household’s discount factor, β , lies between zero and one.

³ We cannot possibly do justice to the literature. Instead we point the interested reader to Barro (1981), Benhabib and Farmer (1999), Bernanke and Woodford (1997), Farmer (1999), Pesaran (1987), Sargent and Wallace (1973), Taylor (1977), and the references therein. Although these studies differ along various dimensions, they refer to indeterminacy of the rational expectations equilibrium. It is important to keep in mind as McCallum (1983) argues, however, that the non-uniqueness problem is a more general feature of dynamic models that involve expectations and not a particular one attributable to the rational expectations hypothesis.

⁴ Benigno and Benigno (2006) and Benigno et al. (2007) study how the indeterminacy regions of the parameter space vary with regard to different types of monetary policy rules in a dynamic general equilibrium model with two similar countries. De Fiore and Liu (2000) and Zanna (2006) study how determinacy of the equilibrium depends on the degree of openness of a small economy, among other things.

⁵ Strictly speaking, the ‘butterfly effect’ as described by Stewart (1990) refers to the sensitivity of a dynamic system to its initial conditions. Here we use the term ‘butterfly effect’ in a more liberal way to refer to a situation in which something thought to be insignificantly small turns out not to be so.

⁶ See also Justiniano and Preston (2010) for a similar version of the two-country small open economy model.

⁷ The terms *foreign* and *large* are used interchangeably.

⁸ See Clarida et al. (1999), Goodfriend and King (1997), Ireland (2004), and Woodford (2003b) for discussions of the new Keynesian closed economy model.

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