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Measurement error and policy evaluation in the frequency domain ☆

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ABSTRACT

This paper explores frequency-specific implications of measurement error for the design of stabilization policy rules. Policy evaluation in the frequency domain is interesting because the characterization of policy effects frequency by frequency gives the policymaker additional information about the effects of a given policy. Further, some important aspects of policy analysis can be better understood in the frequency domain than in the time domain. In this paper, I develop a rich set of design limits that describe fundamental restrictions on how a policymaker can alter variance at different frequencies. I also examine the interaction of measurement error and model uncertainty to understand the effects of different sources of informational limit on optimal policymaking. In a linear feedback model with noisy state observations, measurement error seriously distorts the performance of the policy rule that is optimal for the noise-free system. Adjusting the policy to appropriately account for measurement error means that the policymaker becomes less responsive to the raw data. For a parameterized example which corresponds to the choice of monetary policy rules in a simple AR(1) environment, I show that an additive white noise process of measurement error has little impact at low frequencies but induces less active control at high frequencies, and even may lead to more aggressive policy actions at medium frequencies. Local robustness analysis indicates that measurement error reduces the policymaker's reaction to model uncertainty, especially at medium and high frequencies.

1. Introduction

Measurement error is well understood to exist in most macroeconomic data. The fact that data are *ex post* revised from time to time indicates how common measurement error can be. For example, the U.S. Bureau of Economic Analysis monthly releases its updated measure of GDP and price indices of recent quarters. In 1983-2009, the average revision without regard to sign is about 1.1% for current-dollar quarterly GDP and 1.3% for real quarterly GDP Fixler et al. (2011, p. 12). Historical data are also *ex post* revised based on more complete information, as well as changes to methodology intended to more accurately reflect economic activities. About every five years, the U.S. government issues comprehensive revisions to past estimates of GDP. The latest July 2009 revisions reach back to 1929.[1] This is of course hardly unique to the United States. One striking

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[1] The Federal Reserve Bank of Philadelphia maintains a real-time dataset of the U.S. economy which consists of 23 quarterly macroeconomic variables from 1965 to the present and includes historical revisions to these variables in great details Croushore and Stark (2001).

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example is China's 2005 GDP revision. In light of the country's first nationwide economic census, China's statistics bureau revised its measure of 2004 national GDP upward by 16.8%. This substantial revision moved China above Italy as the sixth-largest economy in the world in 2004. For variables that are defined as the differences between actual and baseline values, the measurement problems become even acuter under structural change when baseline values may vary unpredictably. As an example, Orphanides et al. (2000) and Orphanides and van Norden (2002) empirically documented errors in the measurement of the output gap for the U.S. economy, a part of which arise from the unobservable baseline of potential GDP. This type of data noise is serious when it is difficult to distinguish temporary shocks from permanent changes.

Monetary policy must be made in real time and so necessarily uses noisy data. Standard policy rules represent mappings from current and past economic conditions to monetary policy instruments such as the money supply or interest rates. For example, the famous Taylor (1993) rule is a linear mapping of observations of inflation and the output gap to the federal funds rate. At the time of the interest rate choice, the data available are therefore preliminary and with considerable measurement noise. In short, policymakers must live with and account for measurement error. But how should measurement error affect policy choices? How does measurement error affect the robustness properties of policy rules when the knowledge about fundamental economic structures is imperfect? Does this information constraint justify policy cautiousness, and if it does, how? Considering the possibly large welfare costs and long-lasting economic consequences associated with inflation and economic fluctuations, these questions are important in assessing alternative monetary policies.

To address these issues, this paper contributes to the policy evaluation literature by investigating the implications of measurement error for the design of stabilization policy rules in the frequency domain. As pointed out by Orphanides (2003), this informational limitation on the true macroeconomic variables facing policymakers has been noticed in policy analysis since at least Friedman (1947). Orphanides' (2001, 2003) own work largely reignites research interest in monetary policy evaluation with noisy information; recent contributions include Aoki (2003), Coenen et al. (2005), Croushore and Evans (2006), Molodtsova et al. (2008), and Orphanides and Williams (2002) among others. Many of these studies focus on the use of real-time data and evaluate the performance of real-time policies against *ex post* revised data.[2] However, there has yet to be any systematic examination of the role of measurement error on policy choice in the frequency domain. Frequency domain approaches have been part of macroeconomic analysis for several decades – Hansen and Sargent (1980), Whiteman (1985, 1986),Sargent (1987) are standard examples – and have recently experienced a resurgence in the context of policy evaluation [*e.g.*, Brock and Durlauf (2005), Brock et al. (2008a) and Hansen and Sargent (2008, Chapter 8)]. The current paper develops strategies to characterize frequency-specific performance of alternative policy rules in exposure to data noise.

There are significant reasons why frequency-specific analysis is important for policy evaluation. First, a full characterization of policy effects frequency by frequency is informative to policymakers. In the frequency domain, stabilization policy may be understood as determining the spectral density matrix of the state variables concerned. A full understanding of the effects of a policy rule requires evaluating how cycles at all frequencies are reshaped by the policy. When variances at some frequencies have greater social welfare costs than variances at other frequencies, it is necessary to know frequency-specific performance of alternative policies in order to make sound policy recommendations. This differential weighting of variance by frequency will occur, for example, when the social loss function involves non-time-separable preferences Otrok (2001). In the case of committee policymaking, it is possible that some committee members care more about performance at low frequencies while others care more about performance at high frequencies, hence this information is needed to allow for successful group decisionmaking.

Second, a number of properties of stabilization policies can really only be understood in the frequency domain. Policies that perform well at all frequencies are naturally appealing to policymakers regardless of their preferences. However, it turns out that such policies do not exist. Even if a policy reduces aggregate variance relative to some baseline, for the framework I study this will necessitate increasing variance at some frequencies in exchange for reducing variance at others. These tradeoffs are known as design limits. They were first identified by Bode (1945) in the engineering literature of linear system control and were introduced into the study of feedback policy rules in macroeconomics by Brock and Durlauf (2004, 2005) with extension to the vector case with forward-looking elements developed by Brock et al. (2008b). These design limits are sufficiently complicated in the time domain as to render use impractical outside of the frequency domain.

In this direction, the current paper contributes to the existing literature by studying design limits in the presence of measurement error. As such, the paper extends the study of design limits to the empirically salient case in which a policymaker is ignorant the true state of the economy due to measurement imperfections. In the linear feedback control system, the presence of measurement error creates new design limits than those that have been identified. Intuitively, a feedback policy rule introduces undesirable side noise into the system responding to noisy data, when it exerts influences on the state variable to stabilize the economy. And when the responses are aggressive, the side noise effects are also strong. Therefore, good variance-reducing control has to be traded off against suppression of side noise. Put differently, facing noisy data the policymaker has to make tradeoffs across frequencies as well as between the channels of stabilizing control effects and side noise effects. These constraints are summarized by two concepts – Bode's (1945) integral formula and the complementary

[2] For example, Orphanides et al. (2000) and Orphanides and van Norden (2002) showed that measurement errors are significantly large in real-time estimates of the output gap so as to render the estimates highly unreliable as guides to policymaking if data noise is not appropriately accounted for.