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# Counterfactual analysis in macroeconometrics: An empirical investigation into the effects of quantitative easing

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ABSTRACT

This paper develops tests of policy ineffectiveness when counterfactual outcomes, namely the predicted values of the target variable in the absence of a policy change, are obtained using reduced form or final form 'policy response equations'. The policy response equation explains the target variable by lags of itself and by current and lagged values of the policy variable and policy-invariant exogenous variables. These tests complement those in Pesaran and Smith (2015), which are done in the context of complete systems of macroeconometric dynamic stochastic general equilibrium (DSGE) under rational expectations (RE). While there would be efficiency gains from using the complete system, were it fully known and correctly specified, this is rarely the case. Instead, since the counterfactual is a type of forecast and parsimonious models tend to forecast better than complex ones, we may obtain more reliable estimates of the counterfactual outcomes from a parsimonious policy response equation. We consider two types of policy intervention, a discretionary policy change where there is a deterministic change to the policy variable, and a rule-based policy change where one or more parameters of a stochastic policy rule are changed. We examine the asymptotic distributions and power of the tests under various assumptions. The proposed test for a discretionary policy change is illustrated with an application to the unconventional monetary policy known as quantitative easing (QE) adopted in the UK.



## 1. Introduction

This paper develops tests for the null hypothesis of the ineffectiveness of a policy intervention where the counterfactual, the predicted outcome for the target variable in the absence of a policy change, is provided by a parsimonious reduced form or final form "policy response equation". It complements Pesaran and Smith (2015, PS), which considers tests of policy ineffectiveness in the context of complete macroeconometric dynamic stochastic general equilibrium (DSGE) systems under rational expectations (RE). The policy response equation, which can be derived from the complete system considered in PS, explains the target variable in terms of its lagged values; the policy variable, which may be endogenous or exogenous, and, if available, other exogenous variables and their lagged values that are invariant to the policy intervention.[1] We consider two

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[1] We assume that one can distinguish between those variables that are influenced by policy, and those that are invariant to policy, namely they remain unaffected by the policy change.

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types of policy intervention: discretionary, where there is a deterministic change to the policy variable, and rule-based, where one of more parameters of a stochastic policy rule are changed.

In the case where the underlying model is static, the policy response equation is the reduced form model for the target variable, but in the dynamic case the reduced form also involves lagged values of the other endogenous variables. To obtain the final form equation, the lagged values of these other endogenous variables can be solved out, following the seminal work of Zellner and Palm (1974). This yields an infinite order distributed lag function relating the target variable to the policy and policy-invariant variables (if any). Assuming that the target variable adjusts to policy changes sufficiently fast, the lag orders can be truncated and estimated using standard time series techniques such as Akaike or Schwarz information criteria. Alternatively, following Berk (1974), the lag orders can be set to $T^{1/3}$, where $T$ is the pre-intervention sample size.

To test for the effect of a policy change, we require (i) a model to construct counterfactuals for the target variable in the absence of the policy intervention and (ii) a way to determine whether the difference between the realized and counterfactual outcomes is larger than would have been expected by chance. When the structural model is fully known and correctly specified, using the complete model and imposing all the cross-equation restrictions implied by the DSGE model will yield more efficient estimates of the counterfactual outcomes than using reduced form or final form specifications. However, not only are we rarely certain of the correct specification of individual equations, we often have little knowledge of the subset of the large number of possible variables to include in the full model. In such circumstances, since the counterfactual outcome is a type of forecast, and all the evidence is that parsimonious models forecast better, using a parsimonious policy response equation may produce more reliable estimates of the counterfactual outcomes than a possibly misspecified large model. Accordingly in this paper, we propose tests for policy ineffectiveness based on single equation reduced or final forms and derive their asymptotic distributions both when the post-intervention sample is fixed, as the pre-intervention sample expands, and when both samples rise jointly but at different rates. We also investigate the power of the proposed tests.

A policy intervention can take a variety of forms. The intervention might involve changes to the parameters of either an endogenous policy rule, like the Taylor rule, or an exogenous rule, like a fixed money supply growth rule. Typically, these policy rules are stochastic, in the sense that the policy maker cannot necessarily control the realizations of the policy instrument exactly. Alternatively, the intervention might involve a discretionary deterministic change in the setting of the policy instrument or a shock to the error of a policy rule equation, as is often considered in generating impulse response functions. We will focus on policy interventions that can be characterized either as changes to the parameters of a policy rule or as discretionary policy changes. We note, however, that the testing procedure also applies when the policy intervention is defined in terms of shocks, as argued in PS.

The proposed policy ineffectiveness tests are based on the differences between the post-intervention realizations of the policy target(s) and associated counterfactual outcomes based on the parameters of a model estimated using data before the policy intervention. These differences are computed and averaged over a given policy evaluation horizon. The Lucas Critique is not an issue since the counterfactuals (obtained under the null of no policy change) are computed using pre-intervention parameter estimates, while the effects of policy change, either through changes in parameters or expectations, show up in the realized post-intervention outcomes. *The computation of the proposed tests does not require knowing the post-intervention parameters*.

As an illustration, we employ the policy ineffectiveness tests to investigate the effects of the quantitative easing (QE) introduced in the UK after March 2009. To construct the test, we employ an autoregressive distributed lag (ARDL) equation in the target variable, output growth, the policy variable, the spread between long and short rates, and US and euro area output variables, that we assume to be invariant to the policy change. We exclude other endogenous variables, that could be influenced by the policy. For instance, it would be wrong to include the exchange rate in the equation, because if QE was effective in reducing the spread then the exchange rate would almost certainly have been changed by it and we would have needed to allow for that effect by considering a separate equation that links the exchange rate to QE. By excluding the exchange rate from the policy response equation, we are in effect replacing the exchange rate (which is endogenously determined with the spread) by its determinants. The same argument also applies to any other endogenous variable which is affected by the policy change. This is the reverse of the usual misspecification argument, since we wish to attribute to policy the effects that are transmitted through the other endogenous variables.[2] Following the literature, we treat QE as a discretionary intervention which caused a deterministic 100 basis points reduction in the spread. This policy change has a positive impact effect on output growth of about one percentage point, but the policy impact is very quickly reversed.

The rest of the paper is organized as follows: Section 2 sets up a DSGE model with exogenous variables following PS and derives its solution which is the basis for the single equation policy response functions considered in the rest of the paper. Section 3 provides the framework for the policy ineffectiveness tests. Section 4 develops the test for the static model, where the reduced form equation is used to provide the counterfactual, under both discretionary and rule-based interventions and examines the power of the test. Section 5 extends the test to the dynamic case, where the final form equation is used to derive the counterfactual outcomes. Section 6 considers the empirical application, and Section 7 ends with some concluding remarks. The more technical derivations are given in the Appendix.

[2] A similar argument is developed in a continuous time regression context in Pesaran and Smith (2014).