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LUKAS ELEŞTİRİSİNİN GEÇERLİLİĞİNİN AMPİRİK OLARAK TEST EDİLMESİ

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LIST OF ACRONYMS/ABBREVIATIONS

ADF	:	Augmented Dickey-Fuller
AIG	:	American International Group
CPI	:	Consumer Price Index
CUSUM	:	Cumulative Sum
CUSUM-SQ	:	Cumulatıve Sum of Squares Test
Fig.	:	Figure
GDP	:	Gross Domestic Product
GFC	:	Global Financial Crisis
GSYH	:	Gayri Safi Yurtiçi Hâsıla
GTS	:	General-to-Specific Approach
HAC	:	Heteroskedasticity and Autocorrelation Consistent
LC	:	Lucas Critique
OLS	:	Ordinary Least Squares
PCE	:	Personal Consumption Expenditure
PIM	:	Perpetual Inventory Method
SupEx	:	Superexogeneity Test
QE	:	Quantitative Easing

LIST OF SYMBOLS

π^e	:	Expected Inflation
$V(.)$	:	The Risk Premium
I(1)	:	Integrated of Order One
ECM_{t-1}	:	Error Correction Mechanism ()
DUM_t	:	Dummy Variable

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ABSTRACT

The critique (1976) that made Prof. Robert E. Lucas winner of the Nobel Prize in 1995 has been very influential in the determination and application of macroeconomic policies. The Lucas Critique (LC) is so crucial that it influences almost all econometric research but it does not consider expectations, and so the consequences cannot be reliable. Although the LC was called a hypothesis, since its inception it has been considered as a theory, but importantly, it is still missing solid empirical support. In the light of this information, this thesis consisting of three main chapters, aims to test the validity of the Lucas Critique during the global financial crisis, which forms a basis for fundamental political changes. In order to test the LC empirically, super exogeneity and structural break tests are implemented to a set of models from the literature.

In the first chapter, we attempt to test the validity of the LC through the conventional Phillips Curve and Term Structure Models between 1990 and 2015 using quarterly data. In doing so, we check whether the models carry structural breaks at all the occurrences of quantitative easing (QE) since 2008, including the FED's former chairman Bernanke's speech of QE tapering in May, 2013. Results show that the Lucas Critique is supported for the period of the global financial crisis. Besides, our amended model of the Phillips Curve, with a forward-looking component which validates the importance of future expectations formed by the policy itself does not reveal any breaks between the same sub-samples. In the second chapter, we aim to test the validity of the LC for the substantial change in post-crisis monetary policy of the FED by using the Superexogeneity test, rejection of which lends support to the LC. We make use of quarterly U.S. data from 1990 to 2015. While wealth, Gross Domestic Product (GDP) and Treasury Bill rate are used for the marginal models, the money demand is used for the conditional model. As a result, we reject superexogeneity and our results provide support for the LC. In the last chapter, the effect of government expenditure on GDP in Turkey is

investigated from 2000Q1-2015Q4 by the superexogeneity test. Both conditions of weak exogeneity and structural invariance are satisfied. Therefore, government expenditure is said to be superexogenous to GDP which means that the Lucas Critique is refuted. Moreover, the policy regime shift for the period of the global financial crisis in Turkey did not cause structural variance in government expenditure.

ÖZET

Lukas'ın (1976) Nobel Ödülü almasına büyük katkı sağlayan eleştirisi (LE) makroekonomik politikaların üretilmesi ve uygulanması üzerinde oldukça etkili olmuştur. Oldukça önemli ve etkin bir kavram olan LE, rasyonel beklentiler dikkate alınmadan yapılan bütün ekonometrik çalışmaların sonuçlarının güvenilmez olduğunu iddia etmektedir. İlk ortaya atıldığında "hipotez" olarak tanımlanan bu eleştiri, daha sonra teori olarak kabul görmüştür ama bu derece sarsıcı eleştiri, ampirik olarak köklü bir destek ya da red bulamamıştır. Bu bilgiler ışığında hazırlanan tezim, 3 ana bölümden oluşmakta olup, köklü politika değişikliklerinin yaşanmasına temel oluşturan global kriz dönemi için Lukas Kritiği'nin geçerliliğini literatürde de kullanılan süper dışsallık ve yapısal kırılma testleri kullanılarak ampirik olarak test etmeyi amaçlamaktadır.

İlk bölümde, 1990-2015 yılları arasında 3-aylık Amerika verileriyle Phillips Eğrisi ve Getiri Eğrisi modelleri kullanılarak Global Finansal Kriz dönemi için Lukas Eleştirisi'nin geçerliliği sınanmıştır. 2008'den bu yana yapılan parasal genişlemeler (QE) ve FED eski başkanı Bernanke'nin Mayıs 2013 tarihinde yaptığı konuşmasının modellerde yapısal kırılma meydana getirip getirmediğine bakılmıştır. Çıkan sonuçlara göre Global Finansal Kriz periyodu için, Lukas Eleştirisi geçerlidir. Ayrıca, Phillips eğrisinin bir başka versiyonu olan ileriye dönük bileşen eklenmiş hali, aynı alt periyotlar için kırılma göstermeyerek geleceğe yönelik beklentilerin önemini gözler önüne sermiştir. İkinci bölümde, Global Finansal Kriz akabinde FED tarafından gerçekleştirilen Para Politika değişikliklerinde Lukas Kritiği'nin geçerliliği Süper Dışsallık (Superexogeneity) testi kullanılarak test edilmektedir. 1990-2015 yılları arasında üç aylık dönemlerde derlenen Amerika verileri ile, Servet, Gayri Safi Yurtiçi Hasıla (GSYH) ve Hazine bonosu faiz oranı Marjinal model olarak kullanılırken, para arzı da Koşullu model (Conditional model) olarak kullanılmıştır. Sonuç olarak Süper dışsallık reddedilmiş ve Lukas eleştirisini destekler sonuç bulunmuştur.

Son bölümde ise, Türkiye'de hükümet harcamalarının GDP üzerindeki etkisi 2000-2015 yılları arasında Süper Dışsallık testi kullanılarak araştırılmıştır. Zayıf Dışsallık ve Yapısal değişmezlik şartları sağlandığı için, Türkiye'deki Global Finansal Kriz dönemi için hükümet harcamalarının GDP üzerinde Süper Dışsal olduğu sonucuna ulaşılmıştır. Bu kriz dönemindeki politika rejim değişikliği, hükümet harcamalarında yapısal bir değişime neden olmadığından, Lukas eleştirisini destekler bir sonuç bulunamamıştır.

INTRODUCTION

According to the main argument of the Lucas Critique, any change in economic policy will fundamentally alter the impact of the policy on the economy, because the economic agents form their expectations by considering the future, not the past. That is why policies based on past behaviors of individuals will be misleading. Administering the policies according to the econometric estimation of reduced form equations based on past data will be deceptive since parameters estimated therein will be changed. The LC states that use of any model with ignorance of expectations is inadvisable. Lucas has criticized the use of econometric models in macroeconomics (Linde (2001)). The other remarkable consequence of the critique is questioning intervention in the economy in the course of fiscal and monetary policies. If the critique is absolutely correct, expansionary monetary policies will be precarious since the economic agents are rational and form their expectations according to real variables with the help of perfect information.

Since the LC is fundamentally important, it has a massive volume in the literature (according to Ericsson and Irons (1995) the LC received 513 SSCI citations over 1976-1990) and it has been the subject matter of elite academics' papers in top journals. However, almost all articles are theoretical and/or based on methods like simulation that make no use of real data from markets. In Stanley's (2000) list of empirical papers on the LC, there is a limited number of 13 papers. Besides, some of these papers do not have the main purpose of empirically testing the LC but focus on some other theme (i.e. taxes, monetary union, and central bank governance) and only comment on the LC.

There is a considerable lack of empirical evidence on the LC in the literature the main reason for which is the difficulty in adopting generally accepted methodology. Although Prof. Lucas is alive and active, he and his followers have not introduced methodology to test the critique. Thus, a critical and influential claim

is resting without sound empirical evidence. Another equally important reason, is the lack of opportunity for markets to generate real data for the test.

The main purpose of the thesis is to test the validity of the LC empirically for the global financial crisis period which began in August 2007 in the U.S. and became stronger by the bankruptcy of Lehman Brothers in September 2008. The crisis that arose from the collapse of the U.S. housing sector rapidly expanded to banking and other financial markets as well as all branches of the real economy. The LC analysis became particularly important for the aftermath of the 2008 crisis to assess the effects of consequent policy shifts to stimulate the economy. The thesis consists of three separate chapters which we will now briefly review.

In the first chapter, we make use of U.S. data on the Phillips Curve and Term Structure equations to document that the Lucas Critique is supported for the period of the global financial crisis. Both the Chow Test of structural breaks and CUSUMSQ as well as the behavior of residuals indicate the validity of the Lucas Critique in key monetary relationships during the period. On the other hand, our amended model of the Phillips Curve, with a forward-looking component does not reveal any breaks between the same sub-samples. Additionally, this model validates the importance of future expectations, which are formed by the policy itself. Our findings signify to monetary policy authorities to reconsider and redesign their actions and operations, and to ground their policies on both past data and the behavior of agents.

Our second chapter is the first attempt to use the substantial change in post-crisis monetary policy of the FED to test the validity of the LC. The global financial crisis, triggered by the collapse of the mortgage market in 2007,. presented an invaluable opportunity to test for the LC. We make use of quarterly U.S. data from 1990 to 2015 to test for superexogeneity, rejection of which lends support to the LC. We define the marginal models for wealth, GDP and Treasury Bill rate to construct the conditional model of money demand. We reject superexogeneity and report support for the LC.

The objective of the third chapter is to investigate the effect of government expenditure on GDP in Turkey from 2000Q1-2015Q4 by the superexogeneity test. As a consequence of satisfying both conditions of weak exogeneity and structural invariance, government expenditure is superexogenous to GDP which implies that the policy regime shift for the period of the global financial crisis in Turkey did not cause structural variance in government expenditure. Indeed, the Lucas Critique which indicates that policy regime shifts cause structural breaks, appears to be refuted.

1. TESTING THE VALIDITY OF THE LUCAS CRITIQUE AROUND THE GLOBAL FINANCIAL CRISIS

1.1. INTRODUCTION

In his influential article, Robert E. Lucas (Lucas, 1976) proposed a serious critique on the validity of econometric models to assess economic policy effects. He argued that shifts in policy influence economic activity by altering expectations of the agents, who are forward-looking rather than backward-looking, and thus, adapt their behaviour and expectations according to the new policy conditions. In this case, administering a macroeconomic policy focusing on past experience may produce different outcome, and accurate assessment of the policy effects becomes irrelevant. For this reason, Lucas concluded that reduced-form econometric models become unreliable when the policy action rules are modified, since such changes will alter the actual structural parameters and the estimated coefficients in the model.

Despite its theoretical credibility and the Nobel Prize award in 1995, many researchers have been concerned about the applicability of the Lucas Critique (LC hereafter) in practice (Sims, Goldfeld, and Sachs (1982), Alogoskoufis and Smith (1991), Vanbergeijk and Berk (2001), Lindé (2001), Estrella and Fuhrer (2003), Lubik and Surico (2010a), Smith (2009), Mazumder (2011), and Yildirim & Korap (2012)). The LC analysis became particularly important for the aftermath of the 2008 crisis to assess the effects of consequent policy shifts to stimulate the economy. Surprisingly, there has been no significant research based on an investigation of these effects through the argument of Lucas, which this paper attempts to provide. Furthermore, this period is particularly important due to a series of untraditional expansionary monetary policies such as the quantitative easing (QE) undertaken in the U.S. and in other advanced economies. One of the crucial questions related to the issue has been the relevance of the critique in analysing the future effects of those policies on unemployment and inflation. For instance, according to the short-run prediction of the Phillips Curve (PC), the high unemployment rates during the 2008 recession and subsequent weak recovery should have reduced the inflation rate to below zero. However, Ball and Mazumder

(2014) state that despite this PC prediction, the rate of core inflation[1] in 2015 in the U.S. was close to its before 2008 level. Thus, the 2008 crisis and consequent developments in unconventional policy-making offer a unique opportunity to empirically investigate the case of the LC and its explanation related to modification of the time-series behaviour and parameters in econometric models after the policy changes.

There is a surprising lack of empirical research on the LC in the literature. One of the main reasons has been the absence of a generally accepted methodology. Unfortunately, Lucas and his followers did not introduce research to test the empirical relevance of the theory. Stanley's work (2000) which lists empirical studies on the LC, cites just 13 articles, most of which focus on some other themes (i.e. taxes, monetary union, and central bank governance) and makes comments about the LC rather than having the main purpose of empirically testing it. Despite a large amount of research on the LC[2], almost all of the articles have been either theoretical or based on simulation, which uses limited real data. This is also due to the scarcity of opportunities attributed to a fundamental change in economic policy to generate real data for the test. Indeed, papers on the shift of the Phillips Curve in India due to the CB governor's changes (Mazumder, 2011) or Euro area inflation (Stanley, 2000) comment on the LC but these are far from providing fundamental changes in monetary conditions after the global financial crisis hit.

The aim of the present paper is twofold. First, it attempts to empirically test the validity of the LC through the conventional Phillips Curve and Term Structure Models between 1990 and 2015 using quarterly data. In doing so, it checks whether the models carry structural breaks at all the occurrences of the QE since 2008, including the FED's former chairman Bernanke's speech of QE tapering in May, 2013. Hence, stability over the sample period is here viewed as a test of policy invariance. Secondly, it provides additional evidence on the empirical importance

[1] Core inflation - inflation, excluding the transitory effects of supply shocks.

[2] According to Ericsson and Irons (Ericsson & Irons, 1995) there were 513 SSCI citations between 1976-1990.

of the forward-looking component in inflation and analyses the sources of the discrepancy in econometric estimates between adaptive and forward-looking (constant) inflation expectations. We estimate the conventional Phillips Curve to assess the relative weight of past and after-policy expected inflations and compare the ability of the unemployment gap to explain parameter instability over the sample period and the dynamics of inflation. Our estimations predict that the LC is empirically relevant for the U.S. in the given period, which reveals that econometric analysis cannot be reliable to predict and/or examine the impact of economic policy changes based solely on past data.

1.2. LITERATURE REVIEW

The observable reduced form of the economy and a policy rule for setting the policy instrument can be described as in Lucas (1976) , by

$$Y_{t+1} = F(Y_t, X_t, \theta, u_t)$$

$$X_t = G(Y_t, \delta, \xi_t)$$

in which Y_t is a vector of economic variables, X_t is a vector of policy instruments, θ is a parameter vector, δ is a vector of policy rule coefficients, and u_t and ξ_t stand for the shocks. Lucas indicates that, "A change in policy [in δ] affects the behavior of the system in two ways: first by altering the time series behavior of $[X_t]$; second by leading to modification of the behavioral parameters $[\theta(\delta)]$ governing the rest of the system." The first one is a direct effect of the change in the policy rule on the system. The second effect, which demonstrates changes in the expectations of the agents about the future also triggers changes in the reduced form dynamics of the economy. In this way, influence of the reduced form on the structural policy changes represents the kernel of the Lucas Critique (Rudebusch, 2005).

One main reason behind the scarcity of empirical papers on the LC has been the absence of a widely accepted methodology. Nevertheless, different papers have implemented various empirical approaches and so generalizing available results is challenging and no single conclusion can be reached. Early work by Mills (1988) develops the Bayesian learning model with forward-looking expectations which allows for variance of the parameters when there is a policy change. As a consequence, this study demonstrates that the Bayesian learning model can be a solution to the parameter invariance problem. In the same way, Miller and Roberts 1991) quantitatively test the LC in a BVAR (Bayesian Vector Autoregression) macro model, which is proposed in Litterman (1984), Sims, Goldfeld, and Sachs (1982), Sims (1986), and Doan, Litterman, and Sims (1984). The paper concludes that the results reveal violation of the critique.

Most of the studies tested the LC hypothesis using monetary models. They typically implemented the Phillips Curve, while several studies included the forward-looking element in the model to account for the role of expectations to determine future inflation. The central claim of such re-modelling is that the Central Bank can stabilize inflation at no cost in terms of output or unemployment if future inflation is regarded as a forward-looking phenomenon. On the contrary, lowering the steady-state inflation would require recession in the context of the traditional, backward looking Phillips Curve (Jondeau & Le Bihan, 2005). Alogoskoufis and Smith (1991) stipulate the empirical significance of the LC in the example of the U.S. and U.K. and promote the forward-looking price setters' hypothesis. They demonstrated that there were significant shifts in the coefficient of lagged price inflation and these shifts correspond to similar shifts in the persistence of inflation in both the U.S. and U.K. Yildirim & Korap (2012) test the validity of the LC by using the Turkish narrow money demand function between 1998 and 2010. They considered the money demand as a proper economic aggregate to analyze, since the money demand equation can reflect economic agents' behavior with respect to their monetary holdings. As a conclusion, they could not find empirical evidence to support the LC by using the multivariate co-integration estimation. Castelnuovo

(2008), who re-organizes the Keynesian monetary policy model and uses it to produce artificial data, determines the stability of open-economy backward-looking Phillips Curves for two exchange rate regimes. The model is established for Sweden, which experienced an important regime change in 1992, by replicating the move of a monetary policy break from a Target-Zone regime to a Free-Floating regime, in a similar way to Taylor's (1989). As a consequence, the Lucas Critique is not statistically rejected.

Estrello and Fuhrer (2003) incorporate both forward and backward-looking components into monetary policy models to show that the models' variation according to optimizing behavior and rational expectations does not capture the instability problem. Their study remarks that the LC is not a pure theoretical result but rather is econometric evidence to reveal the importance of stability tests for macroeconomic models. They suggest that every model should be tested for stability before being used for policy analysis. In the same way, Collard, Fève, and Langot (2002) document the quantitative relevance of the LC in their structural model. They concentrate on the potential break in the macroeconomic distribution of the sample to evaluate the effect of changes in monetary policy by holding the parameters of preferences and technology constant.

Leeper and Zha (2003) interpret the behavior of the Federal Reserve by using the VAR model of U.S. monetary policy. They investigate the range of policy interventions, which is made sequentially and not completely different from the past, to check its consistency with an unchanged policy regime. However, McCallum (2005) warns that the VAR models consist of a set of reduced-form equations, where each of a set of variables is regressed on lagged values, with all variables treated as endogenous. Therefore, VAR systems can be more vulnerable to the critique than the traditional models Lucas considered.

Another useful method to check the empirical relevance of the LC focuses on the Term Structure of interest rates (the relation of long-term interest rate to short-term interest rate). Blanchard (1984) analyses the performance of two central

macro-econometric equations, the Phillips Curve and Term Structure of interest rates, after October 1979 with the purpose of investigating the LC. Although, the research could not get a direct effect of policy change on the PC, there was significant evidence of a direct effect on Term Structure. Mankiw, Miron, and Weil (1987) analyse the reactions of expectations by using data on Term Structure around the foundation of the Federal Reserve in 1914. According to their results, when there is a substantial change in the economic policy regime, agents adjust their expectations and conform their behavior to the new environment very rapidly. Vanbergeijk and Berk (2001) analyze the interim period of Euro adoption by Term Structure to detect any structural breaks to test the empirical evidence of the LC. Although their results do not support the LC for most of the European countries in the sample, there is significant structural instability for Germany, the euro area's 'core country', suggesting that econometric policy advice for the euro area as a whole may have suffered from the LC.

The empirical significance of the LC is a crucial issue, especially in the light of unconventional macroeconomic policies since 2008. In the following section, we proceed with the model of the Phillips Curve with both adaptive and anchored expectations to analyse how well they explain the behaviour of actual inflation. This would also let us follow the changes in estimated coefficients. After estimating the model, the study investigates breaks in the structural parameters for the period of all QE developments. To serve as a benchmark for comparison we also implement a Term Structure Model to capture the same breakpoints. In the final part of our estimations, we conduct CUSUM tests to identify instability following on from the LC, as suggested by Chirinko (1988).

1.3. THE PHILLIPS CURVE MODEL

1.3.1. The Traditional Phillips Curve

According to Friedman (1968) inflation is determined by a conventional Phillips Curve augmented to include the role for expected inflation. It is used in the original paper of Lucas as an empirical example as well as in the outstanding papers of Blanchard (1984), Turner (1997), and Mazumder (2011). Friedman's Expectations-Augmented Phillips Curve is expressed as:

$$\pi_t = \pi_t^e + \alpha(u - u^*)_t + \varepsilon_t \qquad \alpha < 0 \tag{1.1}$$

where π is inflation, π^e is expected inflation, u is unemployment, u^* is the natural rate of unemployment, and ε is an error term that is assumed to be uncorrelated with $u - u^*$.

A simple and plausible assumption about the expected inflation is that agents form their expectations of inflation based on recently observed or past inflation. With this assumption, (1.1) becomes:

$$\pi_t = \pi_{t-1} + \alpha(u - u^*)_t + \varepsilon_t \tag{1.2}$$

where π_{t-1} is past inflation. We can re-write this equation as:

$$\pi_t - \pi_{t-1} = \alpha(u - u^*)_t + \varepsilon_t \tag{1.3}$$

Equation (1.3) reveals that α is a parameter measuring the response of inflation change to the unemployment gap or cyclical unemployment. It is assumed that the expectations are backward-looking, so according to our quarterly data, we determine the expected inflation by the average of the last four quarters (Mazumder, 2011). Therefore, equation (1.3) becomes

$$\pi_t - \frac{1}{4}(\pi_{t-1} + \pi_{t-2} + \pi_{t-3} + \pi_{t-4}) = \alpha(u - u^*)_t + \epsilon_t \tag{1.4}$$

which is a special case of the backward-looking Phillips Curve estimated by Gordon (1982), Gordon (2013), Stock and Watson (1999), Stock and Watson (2008), and Ball and Mazumder (2011).

Although the most common approach is to use the New Keynesian Philips curve (NKPC) which is based on the assumption of time-contingent price adjustment, we prefer to choose the Friedman's Expectations-Augmented Phillips Curve with whom the backward-looking component can be tested solely, and comparison opportunity arises between the PCs with the adapted and the anchored expectations.

The backward-looking Phillips Curve has been used in a number of empirical works such as Fuhrer (1997), Jondeau and Le Bihan (2005), Gordon (2013), and Ball and Mazumder (2014) and seem to explain fairly well the U.S. inflation dynamics until 2008. However, in the light of untraditional policy shifts since 2008 such versions of the PC have become significantly prone to the propositions of the LC. Adaptive expectations may be a reasonable premise in some circumstances, but when policymakers undertake credible policy changes, agents can rationally respond by adjusting their expectations of inflation based on the policymakers' decisions rather than past inflation rates. Thus, future inflation may also depend on forward-looking or pre-determined elements based particularly, on the behaviour of those who set the monetary policy.

1.3.2. The Phillips Curve with Anchored Expectations

According to the short-run prediction of the traditional Phillips Curve, high unemployment rates during the 2008 recession and subsequent weak recovery in the U.S. should have dragged the inflation rate below zero. Despite such a PC prediction, the rate of inflation in 2015 was close to its level before 2008. According to Figure 1, the unemployment rate exceeded 10% during the 2008-09 crisis period and was still well above its pre-recession levels with 6% in 2014. However, the inflation rate fell only from 2.4% in 2007Q3 to 2.1% in 2014Q2 with an average inflation rate of 2.1% during this period. Ball and Mazumder (2014) emphasize this phenomenon in their very interesting research of the PC for the U.S. As one explanation, they state that the essential empirical content of the PC with past expectations seemed to have disappeared for the U.S. as they are now anchored at a constant level.

Figure 1.1: U.S. Unemployment and Inflation Rates between 1990 and 2015

Although the FED officially set a 2% target inflation rate in January 2012, debates and preparations for the inflation targeting regime started to ground in the late 1990s (Bernanke & Mishkin, 1997; and Mishkin, 2001). Since 2000, the FED has regularly announced a desired target range for inflation (usually between 1.7% and 2%) measured by the personal consumption expenditure (PCE) price index.

We wondered how the coefficient in the model would change if we replaced the backward- looking content of the PC model with the constant inflation expectations. Taking into account the FED's commitment to the constant target, and therefore, anchored inflation expectations by agents, we replaced the average past inflation in the traditional PC model with the 2.5% fixed rate. We chose 2.5% inflation rate instead of 2% because, as suggested by Ball & Mazumder (2014), since the 1980, the core consumer price index (CPI) inflation (used in our estimations) has continuously exceeded the core PCE inflation by about 0.5% on average (for both the weighted-median and CPIX measures of the core).

With our assumption of the anchored expectations equation (1.4) becomes:

$$\pi_t - 2.5 = \alpha(u - u^*)_{t-1} + \epsilon_t \tag{1.5}$$

If the estimated coefficients in (1.3) and (1.4) differ significantly, this would additionally support the empirical relevance of the LC, which suggests that the traditional implication of the PC may not be relevant any more since the expectations of agents change together with policy shifts rather than being dependent solely on the past experience of the inflation rate.

1.3.3. Breakpoint Tests

A prominent test in the literature to test the validity of the LC belongs to Gregory Chow (1960). The test checks if its statistic asymptotically follows the F-distribution, conditional on well-behaved (identically and independently distributed) errors. (Castelnuovo, 2008; Estrella & Fuhrer, 2003; Lindé, 2001; Lubik & Surico, 2010; Rudebusch, 2005; Smith, 2009; and Van Bergeijk & Berk, 2001a). Consequently, the Chow test is used to detect if there is a structural change in the relationship between the dependent variable Y and the independent variables in the regression model of time series data at different periods. In doing so, the residual sum of squares (RSS) of the regression in the desired periods is estimated

and checked to see how different they are, indicating the existence of a structural break. The corresponding F-statistic is:

$$F = \frac{(RSS_R - RSS_{UR})/k}{(RSS_{UR})/(n_1 + n_2 - 2k)} \sim F_{[n_1+n_2-2k]}$$

where RSS_R and RSS_{UR} are restricted and unrestricted RSS, respectively; n_1 and n_2 are the number of observations belonging to the first and second periods; and k is the number of partial regression coefficients estimated.

Also, we perform Wald and Likelihood-Ratio (LR) breakpoint tests whether the coefficients in a time-series regression vary over the periods defined by our known break dates.

Testing a structural break with a known break date could be constructed by fitting a linear regression with an indicator variable:

$$y_t = x_t\beta + (b \leq t)x_t\delta + \epsilon_t$$

Wald and LR statistics are used to test the null hypothesis of no structural break which is $H_0: \delta = 0$. Both are distributed with $\chi^2(k)$, where k is the number of parameters in the model.

A model with multiple breaks can be expressed as:

$$y_t = x_t\beta + x_t\{(b_1 \leq t \leq b_2)\delta_1 + (b_2 \leq t \leq b_3)\delta_2 + \cdots + (b_m \leq t)\delta_m\} + \epsilon_t$$

where $b_1, \ldots, b_m$ are $m \geq 2$ break dates and the null hypothesis of no structural break is a joint test given by $H_0: \delta_1 = \cdots = \delta_m = 0$.

1.3.4. Results for the Phillips Curve with Adaptive and Anchored Inflation Expectations

Table 1.1 displays the estimates of equations (1.4) and (1.5). We break our sample (for both regressions) into two periods: before the first QE conducted in December 2008 (1990Q1-2008Q3) and after it (2008Q4-2015Q4). The series were checked for the unit roots, and the stationarity of variables was considered before the estimation (provided in Appendix A.1.). The regressions are estimated by Ordinary Least Squares (OLS) using heteroskedasticity and autocorrelation consistent (HAC) (Newey-West) errors to account for serial correlation and heteroscedasticity problems.

In the Phillips Curve with adaptive expectations, for the full sample, the estimated coefficient of unemployment is -1.54, which is significant at 1% level. This result implies that one percent upward deviation of the unemployment from its steady-state level, reduces inflation by 1.5%. Although the relationship is negative and supports the traditional Phillips Curve, the response of the inflation with coefficient of 1.5% is higher than what real practice has shown in the U.S. The result of the first sub-sample implies that there is no significant relationship between the two variables, while in the second sub-sample, although the relationship is empirically significant, the estimated coefficient is still high with -2.1. Furthermore, such notable changes in the estimated coefficients relative to the sample-groups can be indicative of the presence of structural breaks in the data set and hence, the Lucas Critique.

To evaluate the empirical relevance of the LC, we conducted the Chow breakpoint test in the following steps. As the main break-point in the whole time-series data we chose the first time the quantitative easing policy was conducted, in the fourth quarter of 2008. Table 1 shows that the computed F-value is significant at 5% level, which validates that the two subpopulation variances are not the same. Therefore, the LC is valid for post 2008 policies in the U.S. for the Phillips Curve, which indicates it could be deceptive to focus on the past when economic

consequences of the post-crisis policies are determined.

The estimates of the PC with anchored or constant expectations are also displayed in Table 1.1. There are some interesting points to mention. First, for the whole sample, the estimated coefficient of unemployment is -0.619, which is considerably lower than the coefficient, estimated with equation (1.4). Such a lower coefficient is more consistent with reality, since the U.S. did not experience the prolonged disinflationary process associated with the post-crisis high rates of unemployment. The monetary authorities have also been explaining this phenomenon by their credible policies and the role of the well-anchored expectations that would help them keep inflation stable, while stabilizing the economy after the onset of the 2008 financial crisis (Yellen, 2013).

Returning to our regression results with anchored expectations, the first sub-sample of 1990Q1-2008Q3 shows an even lower coefficient with -0.461. Another interesting point to mention is that the second sub-sample implies that unemployment deviation cannot be a significant explanatory variable for estimation of future inflation. One interpretation is that future inflation started to become an outcome of peoples' expectations of the FED policy rather than a direct effect of output gap, typically caused by exogenous shocks.

The breakpoint tests for the PC with anchored expectations for the point of the first QE is provided below the regression estimates in the same table. The test results reveal that when we estimate the model with policy expectations rather than adaptive expectations it does not result in any breaks in the structural parameters between the sub-periods.

Table 1.1: Estimation Results for the Phillips Curve with Adaptive and Anchored Inflation Expectations

Milton Friedman's Phillips Curve $\pi_t = \frac{1}{4}(\pi_{t-1} + \pi_{t-2} + \pi_{t-3} + \pi_{t-4}) + \alpha(u - u^*)_{t-1} + \epsilon_t$			
	1990Q1-2015Q4	**1990Q1-2008Q3**	**2008Q4-2015Q4**
Estimate of α **S.E.**	-1.54** (0.678)	-0.611 (0.636)	-2.105** (0.834)
$\overline{R}^2$	0.168	0.029	0.277
Chow Breakpoint Test **QE I[3] (2008Q4)**			
F-statistic		**Prob. F(1,102)**	
5.003**		0.0275	
Wald Test **QE I (2008Q4)**			
Chi-Square		**Prob. Chi-Square(1)**	
5.0086**		0.0252	
Likelihood-Ratio Test **QE I (2008Q4)**			
Chi-Square		**Prob. Chi-Square(1)**	
4.985**		0.0256	
Phillips Curve with Anchored Inflation Expectations $\pi_t = 2.5 + \alpha(u - u^*)_{t-1} + \epsilon_t$			
	1990Q1-2015Q4	**1990Q1-2008Q3**	**2008Q4-2015Q4**
Estimate of α **S.E.**	-0.619* (0.3513)	-0.461 (0.296)	-0.712 (0.618)
$\overline{R}^2$	0.059	0.035	0.058
Chow Breakpoint Test **QE I (2008Q4)**			
F-statistic		**Prob. F(1,102)**	
0.26		0.611	
Wald Test **QE I (2008Q4)**			
Chi-Square		**Prob. Chi-Square(1)**	
0.192		0.66	
Likelihood-Ratio Test **QE I (2008Q4)**			
Chi-Square		**Prob. Chi-Square(1)**	
0.258		0.611	

Note: ***, ** and * indicates rejection of the null hypothesis at the 1%, 5% and 10% significance level, respectively.

[3] Quantitative Easing One (December 2008 to March 2010)

1.3.5. Stability Tests for the Major Policy Occurrences

Table 1.2 displays the breakpoint test results for the major monetary policy developments in the U.S. since 2008. These include three rounds of QE policies, and former FED chairman Bernanke's first announcement on the possible tapering[4] of the QE. The tapering talk is particularly important because of the significant economic and financial consequences following the announcement (Rai & Suchanek, 2014).

We used the traditional PC with adaptive expectations to detect if the policy changes impact the stability of the parameters in the estimation model. As we can see, the test statistics stress rejection of the null hypothesis in all cases which indicates the validity of the LC for the post 2008 monetary policy in the U.S. Our findings emphasize the importance of the LC as an effective tool in policy-making when undertaken with care and used effectively. Of course, we should mention the not less important role of the policymakers' credibility in order for the LC to work in practice and to assist in minimizing the costs of the policies undertaken.

[4] The FED eventually increased the Federal Funds Rate in December 2015.

Table 1.2: Breakpoint Tests for the Major Policy Occurrences since 2008.

Milton Friedman's Phillips Curve	
Chow Breakpoint Test QE II[5] (2010Q4)	
F-statistic	**Prob. F(1,102)**
7.89***	0.006
Wald Test QE II (2010Q4)	
Chi-Square	**Prob. Chi-Square(1)**
7.889***	0.005
Likelihood-Ratio Test QE II (2010Q4)	
Chi-Square	**Prob. Chi-Square(1)**
7.747***	0.005
Chow Breakpoint Test QE III[6] (2012Q3)	
F-statistic	**Prob. F(1,102)**
8.729***	0.003
Wald Test QE III (2012Q3)	
Chi-Square	**Prob. Chi-Square(1)**
8.735***	0.003
Likelihood-Ratio Test QE III (2012Q3)	
Chi-Square	**Prob. Chi-Square(1)**
8.545***	0.003
Chow Breakpoint Test BTT[7] (2013Q2)	
F-statistic	**Prob. F(1,102)**
6.617**	0.011
Wald Test BTT (2013Q2)	
Chi-Square	**Prob. Chi-Square(1)**
6.619**	0.01
Likelihood-Ratio Test BTT (2013Q2)	
Chi-Square	**Prob. Chi-Square(1)**
6.539**	0.01

Note: ***, ** and * indicates rejection of the null hypothesis at the 1%, 5% and 10% significance level, respectively.

[5] Quantitative Easing Two (November 2010 to June 2011)
[6] Quantitative Easing Three (September 2012 to December 2013)
[7] Bernanke's Tapering Talk (May 22, 2013)

1.4. THE TERM STRUCTURE MODEL

In this section we analyse the post 2008 period policy changes by Term Structure methodology, following Blanchard (1984), and Van Bergeijk and Berk (2001). This methodology would first, serve as a benchmark for comparison with the PC model in the previous section, and second, provide wider framework to investigate the stance of the monetary changes in terms of the interest rates.

Term Structure, which is the relation of the long interest rate to the short interest rate (also the relationship between interest rates or bond yields and different terms or maturities) plays a central role in the economy by reflecting expectations of agents about future changes in interest rates and monetary policy conditions. This model, which in a nutshell, is representation of the expectations theory of the Term Structure was also used by Blanchard (1984):

$$R(n,t) = \alpha_0 + \beta_0 R(m,t) + \sum_{i=1}^{10} \beta_i R(m,t-i) + \sum_{i=1}^{10} \gamma_i \pi(t-i) + \delta_0 V(t) + \varepsilon(t)$$

$$\varepsilon_t = \rho\varepsilon(t-1) + u(t)$$

where $R(n,t)$ and $R(m,t)$ are the long-term and short-term interest rates at time t, respectively, $\pi(.)$ is the inflation, and $V(.)$ is the risk premium. The risk premium $V(.)$ is proxied by an exponential moving average of the variance of the short-term interest rates and the disturbance term ε is modelled as a stationary first-order autoregressive process, with parameter ρ, and u is defined as white noise. The distributed lag structures are third-degree polynomials.

Blanchard (1984) used this model for the purpose of finding the relevance of the Lucas Critique for periods of different FED chairmen and it was indicated that Term Structure is very much subject to the Lucas Critique, since the movement of short and long rates is identified by the expectations hypothesis. In a similar manner, the model explains that the long rate is approximately a weighted average

of current and expected future short rates as well as inflation.

Table 1.3 displays the results of the term-structure model. The variables were tested for the unit roots (provided in Appendix A.1.) and the regression was estimated using the HAC (Newey-West) errors to alleviate heteroscedasticity and serial correlation problems. The coefficient of the current short-term rate and the lagged inflation in all orders seem to be insignificant, although, the former gains significance at higher-order polynomial levels. The stability tests for the same subsamples are reported in Table 1.4. The results are similar to those in the PC model; we reject the null hypothesis in all cases, indicating that each period is significantly different from previous ones. Thus, our findings from the Term Structure Model strengthens our results of parameter instability in the given period and imply strong existence of the LC, associated with post crisis policies in the U.S.

Table 1.3: Estimation Results for the Term Structure Model

Term Structure

$$R(n,t) = \alpha_0 + \beta_0 R(m,t) + \delta_0 V(t) + \sum_{i=1}^{10} \beta_i R(m,t-i) + \sum_{i=1}^{10} \gamma_i \pi(t-i) + \varepsilon(t)$$

	1990Q1-2015Q4
Coefficient for α_0 **S.E.**	4.919*** (0.29)
Coefficient for β_0 **S.E.**	0.080 (0.496)
Coefficient for δ_0 **S.E.**	11.301*** (3.774)
PDL01_ShortTerm **S.E.**	-0.174 (0.188)
PDL02_ShortTerm **S.E.**	0.085* (0.048)
PDL03_ShortTerm **S.E.**	-0.009* (0.004)
PDL04_ShortTerm **S.E.**	0.0002 (0.0005)
PDL01_InflationR **S.E.**	-0.023 (0.444)
PDL02_InflationR **S.E.**	0.002 (0.068)
PDL03_InflationR **S.E.**	0.001 (0.005)
PDL04_InflationR **S.E.**	-0.0001 (0.0007)
R^2	0.178

Note: ***, ** and * indicates rejection of the null hypothesis at the 1%, 5% and 10% significance level, respectively.

Table 1.4: Breakpoint Tests for the Term Structure Model

Term Structure	
Chow Breakpoint Test - QE I (2008Q4)	
F-statistic	**Prob. F(11,82)**
15.39***	0.000
Wald Test - QE I (2008Q4)	
Chi-Square	**Prob. Chi-Square(11)**
169.357***	0.000
Likelihood-Ratio Test - QE I (2008Q4)	
Chi-Square	**Prob. Chi-Square(11)**
116.496***	0.000
Chow Breakpoint Test - QE II (2010Q4)	
F-statistic	**Prob. F(11,82)**
8.71***	0.000
Wald Test - QE II (2010Q4)	
Chi-Square	**Prob. Chi-Square(11)**
95.849***	0.000
Likelihood-Ratio Test - QE I (2010Q4)	
Chi-Square	**Prob. Chi-Square(11)**
80.518***	0.000
Chow Breakpoint Test - QE III (2012Q3)	
F-statistic	**Prob. F(11,82)**
5.36***	0.000
Wald Test - QE III (2012Q3)	
Chi-Square	**Prob. Chi-Square(11)**
59.019***	0.000
Likelihood-Ratio Test - QE III (2012Q3)	
Chi-Square	**Prob. Chi-Square(11)**
56.386***	0.000
Chow Breakpoint Test - BTT (2013Q2)	
F-statistic	**Prob. F(11,82)**
4.03***	0.000
Wald Test - BTT (2013Q2)	
Chi-Square	**Prob. Chi-Square(11)**
48.095***	0.000
Likelihood-Ratio Test - BTT (2013Q2)	
Chi-Square	**Prob. Chi-Square(11)**
44.992***	0.000

Note: *** Indicates that the relevant null hypothesis is rejected at the 1% level of significance

1.5. THE CUMULATIVE SUM OF SQUARES TEST (CUSUM-SQ)

The CUSUM (cumulative sum) and CUSUM-SQ (cumulative sum of squares) tests which were introduced by Brown, Durbin, and Evans (1975) and described in Harvey (1981) have been used for testing the constancy of the coefficients in the model. These tests take the cumulative sum of recursive residuals and plots its value against the upper $[T, \pm 3a(T-k)^{\frac{1}{2}}]$ and lower $[k, \pm - a(T-k)^{\frac{1}{2}}]$ bounds of the 95% confidence interval at each point. ($a = 0.948\ for\ 95\%\ level$).

The CUSUM-SQ method is preferred over the CUSUM test as it is very powerful in detecting changes in the conditional model parameters, especially in the presence of weak serially correlated errors. It is also very robust to non-predetermined (endogenous) regressors in case of stationarity and cointegration, while the CUSUM test can be robust only in the former case (Caporale & Pittis, 2004). If the cumulative sum of squares overflows from the area between two critical lines, then it means that the test detects parameter instability. Also, in the literature these tests are used in the light of the Lucas Critique such as Chirinko (1988), Caporale (1996), Urbain and Lahaye (1992), and Belke (2000).

The CUSUM of squares test is based on the test statistic:

$$S_t = \left(\sum_{r=k+1}^{t} \omega_r^2\right) / \left(\sum_{r=k+1}^{T} \omega_r^2\right)$$

for $t = k+1, \dots, T$, where ω is a recursive residual.

When there is parameter constancy, the expected value of S_t is

$$E(S_t) = (t-k)/(T-k)$$

which goes from zero at t=k and to unity at t=K (See Brown, Durbin, and Evans (1975)).

Figure 1.2 illustrates the CUSUM-SQ of the Phillips Curve, which brings out similar results to those, estimated with other instability tests. The breakdown of the parameter constancy can be observed from the beginning of the 2000s for the first decade, with the largest deviation around the 2008 crisis period. In a similar manner, remarkable breaks in the residual plot can be pointed out on the same dates (Figure 1.3).

Figure 1.2: CUSUM-SQ of the Phillips Curve

Figure 1.3: Residual Plot of the Phillips Curve

The results of the CUSUM-SQ of the Term Structure Model and its residual plot are displayed in Figures 1.4 and 1.5, respectively. We can conclude that the model is quite unstable, as the deviations of the residuals from the critical lines occupy a considerable part of the whole period.

Figure 1.4: CUSUM-SQ of the Term Structure Model

Figure 1.5: Residual Plot of the Term Structure Model:

1.6. CONCLUDING REMARKS

The Lucas Critique suggests that before undertaking any policy, policymakers should consider not only the role of past experiences, but also future formation of expectations which is largely based on the policy itself. In this paper, we attempted to empirically investigate this issue for the U.S. through different prominent models during the period of the biggest policy changes after the 2008 crisis. The period is crucial in the history of American economic policy-making in terms of the introduction of the QE, followed by the adoption of an inflation-targeting regime and re-stabilization of zero-bound interest rates by tapering original monetary easing. These policies would certainly have significant impact on unemployment and inflation, and the LC appears as an important element to explain these effects.

Our findings comment on the validity of the LC during the period of unprecedented fundamental changes in monetary policy in the aftermath of the global financial crisis. Moreover, we find that the PC model with anchored inflation

expectations predicts more accurately the actual outcome of the relationship between inflation and unemployment. While we detected parameter instabilities in all major policy changes with the traditional PC model, the same model with anchored inflation expectations does not carry any breaks between the same sub-samples. This can be a possible explanation of the absence of prolonged disinflation in the U.S. despite the high unemployment rates that existed for a while after the 2008 crisis. The alternative Term Structure Model also revealed existence of the LC for the same sample. Similar parameter instabilities were detected in the Term Structure Model which strengthened our view of the strong presence of the LC in key monetary relationships.

APPENDICES

Appendix A.1.1: Augmented Dickey-Fuller (ADF) Test Results

	Model	Level	
		ADF	**Prob.**
$\pi_t - \frac{1}{4}(\pi_{t-1} + \pi_{t-2} + \pi_{t-3} + \pi_{t-4})$	None	-5.112	0.0000
	Intercept	-4.543	0.0003
	Trend and intercept	-4.489	0.0026
$u - u^*$	None	-2.422	0.0156
	Intercept	-2.864	0.0531
	Trend and intercept	-2.916	0.1616
$\pi_t - 2.5$	None	-2.355	0.0185
	Intercept	-2.349	0.1584
	Trend and intercept	-3.869	0.0163
Long Term Interest Rate, $R(n,t)$	None	-2.810	0.005
	Intercept	-2.332	0.163
	Trend and intercept	-5.399	0.0001
Short Term Interest Rate, $R(m,t)$	None	-1.547	0.114
	Intercept	-1.650	0.453
	Trend and intercept	-3.104	0.110
Exponential Risk Premium, $V(t)$	None	-1.265	0.188
	Intercept	-1.819	0.369
	Trend and intercept	-6.733	0.000

2. LUCAS CRITIQUE AND MONETARY POLICY AFTER THE CRISIS

2.1. INTRODUCTION AND RESEARCH BACKGROUND

The 2008 financial crisis had enormous effects on the global economy and posed challenges on traditional policy making. The so-called credit tsunami of the century, incepted by the mortgage markets, started hitting the financial markets and thus, institutions in June 2007. One of the largest US firms that had been a main pillar of the financial system since 1850, Lehman Brothers, filed for bankruptcy, as well as the American International Group (AIG), a giant insurance conglomerate. The failure of these financial institutions and many others in similar condition triggered the fears that many institutions would be suffering from huge losses due to unpaid borrowings that would threaten their solvency. It did not take long for panic in the financial markets to impact the real markets. In the US, the 18-month recession between 2007 and 2009 was the longest recorded post WWII, as well as compared to 10 other such recessions, the longest of which, had prevailed for 10.5 months. It led to 6.3 % decline in employment and 5.1% fall in output. In the US stock prices fell by 50% from October 2007 to March 2009 ("Recession in Perspective"/Federal Reserve Bank of Minneapolis). The tsunami reached other parts of the globe from the US through financial and trade channels soon enough. The Baltic Dry Index, underlining shipping volume and thus international trade, fell by 50% in October 2008. Japan and Korea had 31% and 26% decreases in their industrial output from January 2008 to January 2009 (Alzaabi, 2013). The global financial crisis in its "Great Recession" stage marked the worst economic contraction since WWII (Verick & Iyanatul Islam, 2010).

When Obama's term at the White House started in 2009, he signed the fiscal stimulus package to increase federal government spending by about $499 billion and reduce taxes by around $288 billion. But alleviating the detrimental influence of the global crisis was extremely complex and beyond such voluminous fiscal policy tools. There was an urgent need for accommodative policies of the monetary authorities. As Mishkin (2011) mentioned, the contractionary shock from the financial crisis was so severe that it overwhelmed the ability of conventional

monetary policy to counteract it. One of the remarkable changes in validating unconventional monetary policy has been the Quantitative Easing (QE) program administered by the US after the crisis, and followed by several other economies. There is a mounting body of recent research on QE and its effects (El-Shagi & Giesen, 2013; Karagiannis, Panagopoulos, & Vlamis, 2010; Frederic S Mishkin, 2011; Rogoff, 2017; Taylor, 2014) and almost all of them agree on the fact that QE was, although risky and not desirable, best possible option to respond to the ongoing and future contractionary shocks to the economy. In the process of implementing QE policies, the FED's balance sheet dramatically expanded from around $700 billion in 2008 to $2.1 trillion in June 2010, with most of the increased absorbed by the banking system as excess reserves (Bernanke, 2012).

QE commenced re-consideration of traditional monetary policy-making, especially in terms of applicability of the Lucas Critique (LC). The LC stipulates that shifts in policy influence economic activity by altering expectations of the agents, who are rather forward-looking, and thus, adapt their behavior and expectations according to the new policy conditions. According to Lucas (1976), policy shifts and/or structural changes of the expectation-generating mechanism lead to unstable econometric models, since such changes will alter actual structural parameters and the estimated coefficients in the model. In order to be an effective policy tool, the econometric model must be invariant to these changes. The role of the LC has become very important in evaluating and analyzing the implications of the policies undertaken after the crisis because it may have a powerful influence in decreasing the application of the standard monetary models for the policy analysis. Applicability of the LC, also known as the validity of "deep structural parameters" (Fair, 1987) is significant to accurately assess the future effects of the consequent policy shifts on economic activity and agents' expectations that are assumed to be "rational".

Some problematic issues arise when the traditional tests in the literature are used in order to find the relevance of the parameter stability with lack of guidance on dates and numbers of breaks or when a wrong break date is chosen (Engle &

Hendry 1993). In such cases, testing for exogeneity with its three different versions is more suitable. While weak exogeneity is employed for estimation purposes, strong exogeneity is required for forecasting, and superexogeneity (SupEx) is facilitated for policy analysis. Although the SupEx test has been used to check for the effects of regime shifts in monetary, exchange rate, consumption and trade policies, there is no attempt on its application with QE in the literature. Despite the QE's significant role as a major shift (and structural parameter) in monetary policy, there has been no research on the issue from the perspective of the LC through SupEx.

In the context of these important policy questions, the present period offers an invaluable opportunity to test the validity of LC empirically. This study applies SupEx test (Engle & Hendry, 1993) to detect the relevance of the LC in modelling the demand for money in the U.S. after the three QE attempts. Most empirical studies suggest that the LC should be assessed in the context of economic models that would deal explicitly with expectations, such as the money demand function used in this paper (Hurn & Muscatelli, 1992; Engle & Hendry, 1993). We also provide policy discussions that shed light on the fragility of conventional models to capture existing information and provide correct policy implications in the environment of major shifts such as QE. Our sample covers the period between 1990 and 2015 for the U.S. in quarterly intervals. Rejection of SupEx over the sample period indicates that the parameters are variant/sensitive to the policy changes and implies that the LC is relevant.

Despite a large amount of research on the LC, there is a surprising lack of empirical study on the issue in the literature. The main reason is the absence of generally accepted methodology. Unfortunately, Lucas and his followers did not introduce the methodology to test the empirical relevance of the theory. In later years, Engle & Hendry (1993) introduced the concept of SupEx, which has appeared to be an effective tool to test the empirical relevance of the Lucas Critique. Subsequent papers (Ericsson & Irons, 1995; Lindé, 2001) have demonstrated how this concept can be applied to check for policy invariance in econometric models.

In this way, SupEx tests have been largely performed to test the effects of regime shifts in monetary, exchange rate, consumption and savings rate behavior (Karunaratne, 1996). The works by Boug (1999), Favero & Hendry (1992), Ericsson & Irons (1995), and Lubik & Surico (2010) highlight the importance of the use of the SupEx test and consider it as the main empirical tool to assess LC validity after the policy shifts.

Analyzing agents' behavior and expectations is essential in setting a credible central monetary policy to control economic activity based not only on past data but the policy itself. As such, our paper addresses an active policy question while also addressing growing concern about the expectations that might, in turn, be shaped based on the post-crisis unconventional programs and behavior of the FED. Yellen (2013) states that well-anchored inflation expectations have proven to be an immense asset in conducting monetary policy after the 2008 crisis. Recent studies stipulate that commitment of the FED to its pre-announced inflation rate and the resulting formation of expectations helped avoid the prolonged disinflationary process associated with the post-crisis high rates of unemployment (Ball & Mazumder, 2014). While adaptive/past-based expectations may be a reasonable premise in some circumstances, predictive monetary policy, transparent communication, and stable expectations play a crucial role, since they influence all sorts of behavior and may help avoid major instabilities predicted by standard modelling.

As mentioned above, there are not many empirical studies based on SupEx methodology to test the LC in monetary models. One study is by Hurn & Muscatelli (1992) who found that the LC may not be relevant in the case of the demand for money (M4) in the UK. Other studies such as Karunaratne (1996), Valadkhani (1998), Caporale (1996), Faria & León-Ledesma (2005), Belke (2000), Oliveira & Santos (2007), Psaradakis & Sola (1996), Santos (2004), and Liu & Morley (2014) investigated the same issue but with applications to trade, consumption, business cycle and financial models. Following the findings in SupEx methodology from earlier studies, this paper is organized as follows. The next section briefly describes

the procedures for testing invariance and SupEx hypotheses. Section 3 outlines and estimates a model of the demand for money in the U.S. The following section 4 provides discussions of the estimated results with policy implications and makes some concluding remarks.

2.2. SUPEREXOGENEITY TESTING

There have been numerous attempts to test the constancy of parameters over the historical period. One of the initial specification tests is by Chow (1960), which simply questions for interactions with dummy variables (Engle & Hendry, 1993). In contrast, SupEx is specifically designed to ascertain whether parameters are likely to remain constant in response to changes in policy regime over the historical period. As an important measure of parameter stability, it is closely related to the test of invariance, but the causes, periods and magnitudes of changes are identified by the economic circumstances, and the historical evidence for regime changes are embodied in the conditioning variables. The SupEx test is perfectly applicable to the models of money demand, and the Phillips curve, in particular. Indeed, the instability of the Phillips curve, especially in times of external shocks and regime changes, was probably the most famous application of the influential "Lucas Critique" (Bajo-Rubio, Díaz-Roldán, & Esteve, 2007). Due to the lack of opportunities of major monetary policy shifts until the global crisis, the SupEx tests were used in applications with exchange rate, consumption, and savings models in the literature. The studies include Ericsson (1992), Favero & Hendry (1992), Caporale (1996), Karunaratne (1996), Valadkhani (1998), and Habibullah, Azali, & Baharumshah (2001) who examine the relevance of the Lucas Critique, in the unique cases of major policy shift.

Exogeneity is the key to many econometric analyses, since models require distinction between exogenous and endogenous variables. However, conceptualization of the term is not made clear (Engle, Hendry, & Richard, 1983) rendering inference on the parameters to further investigation. Engle, Hendry, &

Richard (1983) argue that the SupEx is closely related to the Lucas Critique and, as mentioned in Caporale (1996), serves as an important instrument for policy analysis.

Below is a brief explanation of the SupEx testing procedure employed to assess the relevance of the LC. A more detailed and complete procedure of the testing strategy for superexogeneity is provided by Engle, Hendry, & Richard (1983). We define the joint, conditional and marginal distributions for superexogeneity testing following Engle, Hendry, & Richard (1983) as:

$$F_k(k_t;\theta_t) = F_{y|x}(y_t|x_t;\lambda_{1t}).F_x(x_t;\lambda_{2t})$$

where $F_{y|x}$ and F_x are conditional and marginal models.

A variable x_t is said to be *weakly exogenous* for a set of parameters of interest Ψ (some functions of θ) in a conditional model of a variable y_t with parameters λ_1 with $k_t = (y_t, x_t)'$ if:

i) Ψ is a function of the parameters λ_{1t} alone;

ii) λ_{1t} and the parameters of the marginal model for x_t, and λ_{2t} are variation free, which implies that there is no loss of information about Ψ from neglecting the marginal model (Caporale, 1996)

x_t is defined as *super exogenous* for Ψ if:

i) x_t is weakly exogenous for Ψ,

ii) changes in λ_{2t} do not cause changes in λ_{1t}. Here, a parameter is considered invariant for a class of interventions if it remains constant under these interventions. A model is invariant for such interventions if all its parameters are (Engle et al., 1983).

Illustratively, Engle et al. (1983) model the linear regression equation, which is hypothesized to represent the constant conditional mean of a random variable y_t given another random variable x_t as well as other information. Consider

the joint distribution of these variables conditional normal with the following conditional means:

$$E[y_t|I_t] = \mu_t^y \tag{2.1}$$

$$E[x_t|I_t] = \mu_t^x$$

and covariance matrix

$$\Sigma_t = \begin{bmatrix} \sigma^{yy} & \sigma^{yx} \\ \sigma^{xy} & \sigma^{xx} \end{bmatrix} \tag{2.2}$$

where x_t and y_t are conditional on the information set I_t that contains their past values, and current and past values of other valid conditioning variables z_t. The conditional expectation of y_t on x_t can be expressed as:

$$E(y_t|x_t) = \lambda_t(x_t - \mu_t^x) + \mu_t^y \tag{2.3}$$

and

$$y_t - E(y_t|x_t) = \omega_t \tag{2.4}$$

where λ_t is the regression coefficient of y_t on x_t equals to σ^{yx}/σ^{xx}, and ω_t is the conditional variance equals to $\sigma^{yy} - (\sigma^{yx})^2/\sigma_t^{xx}$.

The conditional mean of y_t and x_t is considered in the following behavioral relationship as:

$$\mu_t^y = \beta\mu_t^x + z_t'\gamma \tag{2.5}$$

Combining Equations 2.3, 2.4 and 2.5 yields:

$$y_t = \beta x_t + z_t'\gamma + (\lambda_t - \beta)(x_t - \mu_t^x) + \omega_t \tag{2.6}$$

To sustain this regression analysis with weakly exogenous, constant and invariant parameters we need the following three conditions:

- *Weak exogeneity* of x_t for the parameters of interest. This requires that μ_t^x, σ_t^{xx}, and σ_t^{yx} do not enter the conditional model, which is satisfied if $\lambda_t = \beta$.

- *Constancy* of the parameters that requires $\lambda_t = \lambda$. Since $\lambda_t = \sigma^{yx}/\sigma^{xx}$, the regression model is homoscedastic if $\sigma^{yy} = \omega + \lambda\sigma_t^{xx}$.

- *Invariance* of β to the changes in the processes generating z_t.

With these conditions satisfied, a standard regression model to be estimated is:

$$y_t = \beta x_t + z_t'\gamma + \omega_t \tag{2.7}$$

Consistent with the Lucas Critique, Engle & Hendry (1993) show that the effects of policy shifts can be formulated as the impact of changes in the moments of x_t on the parameters of β in the following linear expansion form:

$$\beta = \beta_0 + \beta_1\mu_t^x + \beta_2\sigma_t^{xx} + \beta_3(\sigma_t^{xx}/\mu_t^x) \tag{2.8}$$

By substituting (2.8) into (2.7) we obtain:

$$\mu_t^y = [\beta_0 + \beta_1\mu_t^x + \beta_2\sigma_t^{xx} + \beta_3(\sigma_t^{xx}/\mu_t^x)]\,\mu_t^x + z_t'\gamma \tag{2.9}$$

or in the following form as a regression:

$$y_t = \beta_0 x_t + z_t'\gamma + (\lambda_t - \beta_0)(x_t - \mu_t^x) + \beta_1(\mu_t^x)^2 + \beta_2\mu_t^x\sigma_t^{xx} + \beta_3\sigma_t^{xx} + \varepsilon_{1t} \tag{2.10}$$

For SupEx, the moments of x_t should be insignificant and λ_t must be constant over time. However, when Σ_t is not constant, Engle and Hendry (1993) suggest a linear expansion, such as:

$$\lambda_t = \sigma^{yx}/\sigma^{xx} = \lambda_0 + \lambda_1\sigma^{xx} \tag{2.11}$$

By combining Equations (2.6), (2.8), and (2.11) we obtain a general alternative regression for the case of non-constant Σ_t:

$$y_t = \beta_0 x_t + z_t'\gamma + (\lambda_0 - \beta_0)(x_t - \mu_t^x) + \lambda_1(x_t - \mu_t^x)\sigma^{xx} + \beta_1(\mu_t^x)^2 + \beta_2\mu_t^x\sigma_t^{xx} + \beta_3\sigma_t^{xx} + \varepsilon_{2t} \quad (2.12)$$

Equations (2.10) and (2.12) can be implemented to test for SupEx by examining both a conditional model and marginal models for the conditioning variables. The conditional and marginal models can be interpreted as agents' and policy makers' decision rules, respectively (Giersbergen & Kiviet, 1996). Since policy makers often set targets for the endogenous variables that determine the behavior of the economic agents, policy rules are affected from past economic outcomes. (Banerjee, Hendry, & Mizon, 1996). Economically, superexogeneity occurs when the agents form their expectations without using models, for instance the high cost of information or a low level of benefits from model-based expectations. (Ericsson, Hendry, & Mizon, 1998).

2.3. DATA

The data set is quarterly and covers the period between 1990 and 2015. Description of the variables are as follows: MD_t is the log of real money demand (M2); GDP_t is the log of real gross domestic product with 1990 constant prices; TB_t is the 3-month treasury bill rate; W/GDP_t is the real wealth of firms as % of GDP; W_t is the log of real wealth; SMI_t is the log of S&P stock market index; INF_t is the log of GDP deflator; L_t is the log of labor participation ratio; C_t is the log of real capital, and DUM_t is the dummy variable that takes 0 between 1990Q1-2008Q3 and 0 otherwise.

The data of money demand, GDP, and GDP deflator are extracted from Thomson Reuters database. 3-month treasury bill rate, wealth, and labor participation ratio are taken from Federal Reserve Economic Data. Bloomberg Terminal is the source of the Capital data. And finally, S&P stock market index is retrieved from Quandl database.

2.4. MODELS AND TEST RESULTS

The conditional model is constructed with real money demand being a dependent variable. It is identified by a cointegrating vector of both scale variables and the variables represent the opportunity cost of holding money. Similar relationships were documented earlier by Judd & Scadding (1982) and Hurn & Muscatelli (1992) although with differing model specifications and level of analysis.

Hurn & Muscatelli (1992) examined the possible role of the Lucas critique by using UK money demand (M4) over the period 1966Q4-1989Q4. Real Money $(M4 - P)$ is used as the dependent variable in the conditional model in which P is the implicit deflator of GDP and deposit rate, inflation, and wealth are constructed as the marginal models. As a result, they could not find a relevance in the case of the demand for M4.

The scale variables in the money demand function represent wealth effects and transactions. Real wealth, which captures the asset motives of holding money, is proxied by the real total financial assets of the non-financial corporate sector. The other scale variable is real GDP, representing economic activity and hence, transactions based demand for money. The resultant money demand equation is;

$$MD_t = \beta_1 MD_{t-1} + \beta_2 (W/GDP)_t + \beta_3 GDP_t + \beta_4 TB_t + \beta_5 DUM_t \qquad (2.13)$$

The second set of variables denotes the opportunity cost of holding money, which consists of both its own rate and alternative returns on money. We did not include own rate of money, since the current deposits' rates have long been close to zero in the US and do not capture observable changes. As the measure of alternative returns, we added the interest rate on the 3-month US Treasury Bill, regarded as a close money-substitute foregone by holding money. All variables were deflated using the GDP deflator. The corresponding marginal models were constructed for the real wealth, GDP and interest rates which are the explanatory

variables in the Money demand model are represented in below:

$$W_t = \beta_1 W_{t-1} + \beta_2 SMI_t + \beta_3 DUM_t \quad (2.14)$$

$$GDP_t = \beta_1 GDP_{t-1} + \beta_2 L_{t-1} + \beta_3 C_t + \beta_4 DUM_t \quad (2.15)$$

$$TB_t = \beta_1 TB_{t-1} + \beta_2 INF_t + \beta_3 FED_t + \beta_4 DUM_t \quad (2.16)$$

In this section, we report the estimates of the policy reaction function using equations (2.10) and (2.12). We construct the conditional and marginal models congruent with the demand for money in the US to check if the LC is relevant after the post-crisis monetary policy shift.

As stated in the previous section, there are two conditions for SupEx: for the condition of weak exogeneity, the resulting residuals from the marginal model must be insignificant in the conditional model. As for the condition of SupEx (or structural invariance of the parameters), the parameters of the conditional model must be insensitive to induced structural changes in the marginal model parameters. Policy analysis generally involves changing the marginal process of x_t. For a valid analysis under such changes, the parameters λ_1 should be invariant to those changes/interventions. Ericsson, (1992) Hurn & Muscatelli, (1992), Engle & Hendry, (1993), Hendry, (1995) and Valadkhani (1998) state that at an empirical level, the condition of SupEx can be tested by inserting a dummy variable in both conditional and marginal models. This dummy represents the structural change or policy shifts and if it is significant in the marginal model and simultaneously insignificant in the conditional model, the condition of structural invariance is satisfied. However, the null of SupEx will be rejected if the dummy added to the basic conditional model comes out to be significant. The regime shift or structural change dummy variable in this study is defined as DUM_t, which captures the QE policy and takes the value of zero until the fourth quarter of 2008, and one otherwise.

In the first step of estimation, we conducted ADF tests to check for stationarity of the variables and detect their orders of integration. Appendix B.2.1 displays the test results, which reveal that all variables are integrated of order one, I(1).

Below are the estimation results of the parsimonious dynamic conditional model for money demand based on equation (2.13) and derived by the general-to-specific (GTS) approach (Davidson, Hendry, Srba, & Yeo, 1978; Engle et al., 1983). The optimum lag length is selected according to Akaike Information Criterion (AIC)[8] and the insignificant lags are eliminated according to the GTS approach. Johansen Cointegration Test Results are presented in Appendix B.2.2. The short-run dynamics in the model are captured by the cointegrating vector as an error correction mechanism (ECM_{t-1}), which is statistically significant. The included dummy variable is of particular interest to us, since it captures structural changes. As expected, the sign of its coefficient estimate is positive, since the QE policy would induce higher demand for money. Its coefficient is also significant in the conditional model, validating doubts on the condition of the structural invariance. This means that shifts in the monetary regime have significant considerable effect on money demand, highlighting the importance of behavioral factors such as expectations, as stated by the LC.

The serial correlation and heteroscedasticity test results are satisfactory. Furthermore, the cumulative sum (CUSUM) test (Fig.2.1) documents that the regression is stable over the sample period.

[8] According to AIC criterion, lag length is selected 4 for the Conditional Model, 2 for the Marginal Models of Wealth, Treasury Bill Rate, and GDP.

$$\Delta MD_t = -0.003ECM_{t-1} + 0.507\Delta MD_{t-1} + 0.24\Delta MD_{t-3} + 0.044\Delta(W/GDP)_{t-4} -$$
$$[0.002] \quad [0.076] \quad [0.074] \quad [0.022]$$

$$0.24\Delta GDP_{t-1} + 0.358\Delta GDP_{t-3} + 0.001\Delta TB_{t-2} - 0.002\Delta TB_t - 0.045\Delta GDP_t +$$
$$[0.101] \quad [0.088] \quad [0.0005] \quad [0.0005] \quad [0.093]$$

$$0.001DUM_t \qquad (2.17)$$
$$[0.0005]$$

$$ECM_{t-1} = MD_{t-1} + 1.902 * (W/GDP)_{t-1} - 2.469 * GDP_{t-1} + 0.059 * TB_{t-1} +$$
$$[0.634] \quad [1.235] \quad [0.015]$$

$$+19.764$$

$Adjusted\ R - squared = 0.555$
Serial Correlation F (4,90) = 1.548, Prob. F (4,90) = 0.195
Heteroscedasticity ARCH F (4,95) =0.059, Prob. F (4,95) = 0.9934

Figure 2.1: CUSUM of the Conditional Model

In the next step, we estimate the marginal models for x_t, reported in below. The standard errors are in the box brackets. The conditional and the marginal

models appear to be stable and reveal mainly satisfactory diagnostic test results. We should note that the marginal model of GDP was estimated using HAC errors to account for the heteroscedasticity issue detected while testing. The signs of all significant coefficient estimates are consistent with established underlying theory, and the ECM displays significant coefficients in all models. Most importantly, included dummies, which capture a major QE shift, also have significant coefficients in all models. This indicates that implementation of the QE plays a crucial role in modelling the main economic relationships, by validating changes in the actual structural parameters of the econometric models. Our empirical findings ascertain that the parameters in the econometric model of the money demand relationship, which is largely used by policymakers, have changed in response to changes in QE regime after 2008. Therefore, the consequent actions of the economic agents, such as their decisions concerning asset accumulation, economic activity and purchase of bonds would largely depend on their expectations, based mainly on the QE policy itself.

$$\Delta W_t = \underset{[0.009]}{-0.034ECM_{t-1}} + \underset{[0.077]}{0.417\Delta W_{t-2}} + \underset{[0.015]}{0.089\Delta SMI_t} + \underset{[0.001]}{0.002DUM_t} \qquad (2.18)$$

$$ECM_{t-1} = W_{t-1} - \underset{[0.102]}{0.756 * SMI_{t-1}} - \underset{[0.343]}{0.153 * I_{t-1}} - 10.445$$

$Adjusted\ R - squared = 0.400$
Serial Correlation F (2,98) = 2.805, Prob. F (2,98) = 0.065
Heteroscedasticity ARCH F (2,99) =0.551, Prob. F (2,99) = 0.578

$$\Delta GDP_t = \underset{[0.019]}{-0.03ECM_{t-1}} + \underset{[0.083]}{0.463\Delta GDP_{t-1}} + \underset{[0.074]}{0.161\Delta L_{t-1}} + \underset{[0.038]}{0.118\Delta C_t} + \underset{[0.0005]}{0.001DUM_t} \qquad (2.19)$$

$$ECM_{t-1} = GDP_{t-1} - \underset{[0.030]}{0.681 * C_{t-1}} + \underset{[0.155]}{1.049 * L_{t-1}} - 9.039$$

$Adjusted\ R - squared = 0.258$
Serial Correlation F (2,97) = 3.44, Prob. F (2,97) = 0.035
Heteroscedasticity ARCH F (2,99) =3.106, Prob. F (2,99) = 0.049

$$\Delta TB_t = -0.06ECM_{t-1} + 0.629\Delta TB_{t-1} - 0.135 + 31.62\Delta INF_t + 0.135DUM_t \quad (2.20)$$
$$[0.019] \qquad [0.072] \qquad [0.09] \quad [31.895] \qquad [0.078]$$

$$ECM_{t-1} = TS_{t-1} + 46.244 * I_{t-1} + 1.823 * FED_{t-1} - 95.627$$
$$[8.556] \qquad [1.325]$$

$Adjusted\ R - squared = 0.454$
Serial Correlation F (2,103) = 2.37, Prob. F (2,103) = 0.098
Heteroscedasticity ARCH F (2,105) = 1.025, Prob. F (2,105) =0.362

Table 2.1 provides further support to the validity of the LC associated with policy-based expectations. All residuals from the marginal models came out to be insignificant in the conditional model. This shows that the condition of weak exogeneity is satisfied. However, the same is not true for the condition of structural invariance, since the dummy is simultaneously significant in both the marginal model(s) and the conditional model. In this case, it is concluded that the null of SupEx is rejected and the model of the demand for money is prone to the LC.

Table 2.1: Superexogeneity Test Results

Test	Null Hypothesis	t-statistic
Weak exogeneity:	$\varepsilon_t^W = 0$	1.558
	$\varepsilon_t^{TS} = 0$	0.061
	$\varepsilon_t^{GDP} = 0$	-1.635
Invariance:		
Marginal model of W	DUM = 0	1.948*
Marginal model of TB	DUM = 0	1.718*
Marginal model of GDP	DUM = 0	3.356***
Conditional model	DUM = 0	1.802*

Note: ***, ** and * indicates rejection of the null hypothesis at the 1%, 5% and 10% significance level, respectively.

2.5. CONCLUSIONS AND POLICY IMPLICATIONS

Economists agree on the fact that the shocks to the financial system resulting from the global financial crisis were in many ways more complicated compared to those triggered by the Great Depression of the 1930s, and yet, the consequent contraction of economic activity appeared to be less severe Mishkin (2011). Although Taylor (2014) believes that the post-crisis aggressive monetary policy was not as effective as expected, Mishkin (2011) suggests it was the best tool that could be implemented to mitigate the shocks, since the severity of the crisis in 2008 overwhelmed the ability of conventional monetary policy to counteract it. Except for efficiency debates, the regime changes rekindled questions on the Lucas Critique that naturally arise in the environment of major policy shift.

Following the emergence of the LC, monetary models posed challenges in regard to their potency to explain/forecast inflation dynamics and as a policy tool, due to their inability to accurately capture the behavior of the agents after a shift. According to the main argument of Lucas, any change in the macroeconomic policy, such as QE in our case, will alter the expectations of the agents who make assessments by considering the future rather than the past and they will adapt their expectations and behavior to the new policy stance. Lucas stressed on the parameters of the econometric model that become unstable across different policy regimes. Monetary shifts such as the QE policy carry high possibility to alter the structure of past-data-based economic models, as foreshadowed in the LC. If the LC holds, it is deceptive to focus solely on the past when economic consequences of such policies are determined, whereby expectations play a significant role in shaping them. Indeed, the management of expectations about future policy has become a central element of monetary theory with zero-bound policies, as highlighted in Mishkin (2011).

At the same time, the QE period represents in interesting and unique case of study. Our empirical estimates reject the condition of superexogeneity or parameter invariance, providing credibility to the LC. This is contrary to Hurn & Muscatelli (1992) which seems to be the only empirical paper that tests LC validity via SupEx methodology (in the example of the UK money demand). Several other works (Bajo-Rubio et al., 2007; Estrella & Fuhrer, 2003; Leeper & Zha, 2003) generally found no or modest quantitative impact of LC in monetary relationships, while Rudebusch (2005) argues that the main reason why most of the studies fail to detect the LC is that shifts in the policy rule may be unimportant historically. Indeed, the QE period represents the opportunity of radical policy shifts capturing massive liquidity provisions, purchases of both government and private assets, and dramatic expansion of the FED's balance sheet. This might be one explanation for our results that significantly support the validity of the LC in the model of money demand in the US.

In the context of our findings, what policymakers should consider is how to deal with those parameter inconstancies and therefore, with expectations. The instability of monetary models in the presence of structural breaks (following regime shifts) would mean considerable challenge for their use as a policy tool. However, Bernanke (2009) suggests that expectations, if effectively monitored, can rather be used as an additional tool to manage the implications of policy changes, especially in the environment of zero-bound policy. As the current FED chairman Yellen (2013) stressed, management of expectations has proven to be an immense asset in conducting post-crisis policies and minimizing policies' potential costs to the economy.

The theoretical literature strongly supports expectation management to stimulate consumption during the zero-bound period because a commitment to maintain low short-term interest rates for a longer time triggers lower long-term interest rates and simultaneously raises inflation expectations, thereby reducing the real interest rates, and helping to continue zero-bound policies for a long period of time (Eggertsson & Woodford, 2003). With strong commitment, clear

communication and broad guarantees, policymakers can actually get the agents to react more for new policies. Many of the actual programs implemented during the crisis had elements of guarantees, although they could use them more extensively (Caballero, 2010). The IMF (2013) stipulates that providing maximum clarity to the public about the expansionary policies (thereby anchoring long-term inflation expectations) helped the FED avoid prolonged deflation that started after the crisis, and at the same time, increase its flexibility to use securities purchases to provide additional accommodation. For instance, the rate of US core inflation[9] in 2011 was close to its level before 2008, despite the short-run prediction of the Phillips curve that high unemployment rates would drag inflation rates well below zero (Ball and Mazumder 2014). The paper suggests that one of the reasons for this is that the Fed's commitment to a 2% inflation target has kept expected inflation near 2%, which in turn has prevented actual inflation from falling very far below that level.

The use of a monetary policy based on QE1-2-3, overall, was an accomplishment and helpful to mitigate destructive shocks by the financial system. The FED was largely successful in administering and even manipulating the expectations -as suggested by Lucas- and made use of drastic change in the monetary policy regime to keep the growth rate, as well as the unemployment rate, at desirable levels despite the disastrous magnitude of the global financial crisis.

Another example of preparing and managing expectations can be observed in the gradual increase of interest rates with the first actual tightening in December 2015. The increase in the rates was sufficiently small and gradual, accompanied by prior effective communications with the public, having provided clear signals about future tightening. As a consequence, both domestic and international impacts were smooth, while relative depreciation of other currencies against the dollar had started well before the actual FED's tightening. This is largely due to the expectations formed by the speeches of the FED chairpersons from 2013 about their intentions to gradually temper the QE regime.

[9] Core inflation - inflation, excluding the transitory effects of supply shocks.

As Bernanke (2009) mentioned, the FED prompted considerable effort in "developing a suite of tools to ensure that the exit from highly accommodative policies can be smoothly accomplished when appropriate, and FOMC participants have spoken publicly about these tools on numerous occasions". Given the existence of structural breaks and associated expectation changes documented by our results, a central bank commitment that firmly anchors long-run inflation expectations can make an important contribution to the effectiveness of its policies aimed at stabilizing and stimulating economic activity in the face of adverse demand shocks. The recommended acts would include continuing to actively review its communication strategy, and to make its outlook and policy intentions as clear as possible. The commitment to certain nominal anchors is not necessarily limited to inflation expectations, but also extends to other indicators such as money supply and exchange rate. Our evidence of the superexogeneity in this work compatibly highlights the crucial role of the management of expectations, seemingly shaped by the policy itself. Transparency, communication and credible commitment of the central banks have become important elements for successful monetary policy outcomes, which are truly possible under the condition of central bank independence.

APPENDICES

Appendix B.2.1: Augmented Dickey-Fuller (ADF) Test Results

	Model	Level	
		ADF	Prob.
Money Demand	None	3.667	0.999
	Intercept	2.194	0.999
	Trend and intercept	-2.373	0.391
Wealth / GDP	None	1.739	0.979
	Intercept	-0.859	0.797
	Trend and intercept	-1.820	0.688
GDP	None	4.678	1.000
	Intercept	-1.591	0.483
	Trend and intercept	-0.776	0.964
Treasury Bill Rate	None	-1.817	0.066
	Intercept	-2.036	0.270
	Trend and intercept	-4.597	0.001
Inflation	None	4.239	1.000
	Intercept	-2.612	0.093
	Trend and intercept	-2.416	0.368
Wealth	None	2.572	0.997
	Intercept	-1.159	0.689
	Trend and intercept	-1.459	0.837
Stock Market Index	None	2.377	0.995
	Intercept	-1.588	0.484
	Trend and intercept	-1.846	0.675
Capital	None	2.913	0.999
	Intercept	-1.748	0.404
	Trend and intercept	-1.111	0.921
Labour	None	-1.813	0.066
	Intercept	1.695	0.999
	Trend and intercept	-0.87	0.954

Appendix B.2.2: Johansen Cointegration Test

(a) Conditional Model for Money Demand				
	Eigenvalue	**Trace Statistic**	**0.05 Critical Value**	**Prob.****
None*	0.254	59.877	47.856	0.002
At most 1	0.133	28.455	29.797	0.070
(b) Marginal Model for Wealth				
	Eigenvalue	**Trace Statistic**	**0.05 Critical Value**	**Prob.****
None*	0.193	38.421	29.797	0.004
At most 1	0.094	14.979	15.494	0.059
(c) *Marginal Model for Treasury Bill Rate*				
	Eigenvalue	**Trace Statistic**	**0.05 Critical Value**	**Prob.****
None*	0.127	27.693	29.797	0.085
At most 1	0.08	13.129	15.494	0.110
(d) Marginal Model for GDP				
	Eigenvalue	**Trace Statistic**	**0.05 Critical Value**	**Prob.****
None*	0.261	37.467	29.797	0.005
At most 1	0.039	4.395	15.494	0.869

Trace test indicates 1 cointegrating equation at the 0.10 level
* denotes rejection of the hypothesis at the 0.10 level
** MacKinnon-Haug-Michelis (1999) p-values

3. EFFECT OF GOVERNMENT EXPENDITURE ON GDP IN THE TURKISH ECONOMY

3.1. INTRODUCTION

In the literature, although there are plenty of studies that examine the effects of monetary policy shifts (Ball and Mazumder, 2014; Castelnuovo, 2008; Hurn and Muscatelli, 1992; Lindé, 2001; Rudebusch, 2005), there is a lack of empirical support about the impact of fiscal policy which is one of the most interesting and international discussions.

The Global Financial Crisis (GFC) which began in August 2007 in the USA and became stronger by the bankruptcy of Lehman Brothers in September 2008, had an enormous effect on the global economy. The crisis that emerged due to the collapse of the U.S. housing sector rapidly expanded to the banking and other financial markets as well as all branches of the real economy. Both developed and developing economies went into recession and large financial institutions that invested heavily in toxic assets became insolvent.

As opposed to Western banks that suffered heavily from the Global Financial Crisis due to their investment in subprime mortgages, Turkish banks remained relatively strong in this period. The Turkish banking sector was subject to large-scale consolidation after the 2001 economic crisis and many insolvent banks were subject to mergers and acquisitions. After the crisis, regulatory authorities imposed very rigid regulation and supervision of the banking sector and these efforts paid off during the GFC. The balance sheet of the Turkish banking sector did not hold any of the toxic assets that had devastated the balance sheets of large financial institutions all over the world. Therefore, the collapse of global credit markets did not have a direct impact on the banking sector and the industry remained profitable even during the GFC.

Although the banking sector remained relatively strong during the GFC, the same cannot be said for the real economic activity. The Turkish economy was one of the hardest hit countries in terms of the decline in real GDP. As can be seen in

Figure 3.1 the economy went into a recession in the first quarter of 2009 after realizing positive GDP growth for 26 consecutive quarters. Frozen global credit markets and the heavy dependence of the Turkish economy on foreign savings due to the large current account deficit were largely responsible for the rapid decline in economic activity during the Global Financial Crisis.

Figure 3.1: Annual GDP Growth Rates

Source: Turkish Statistical Agency.

The Turkish economy was one of the hardest hit countries during the Global Financial Crisis, but one should also note that the economy experienced a rapid recovery due to the actions taken in the form of monetary and fiscal policies. The Central Bank reduced the policy rate from 19.75% to 8.75% within just a year and this decline in interest rates gave a big stimulus to bank credit volumes. As a result, the economy experienced an average of more than 8% GDP growth in 2010 and 2011 due to the rapid increase in domestic consumption and investment expenditures. Besides monetary policy, the government also used fiscal policy in order to increase the speed of recovery. Tax cuts were introduced in various sectors to increase domestic consumption and government expenditure was increased substantially. As a result, Figure 3.2 demonstrates the expectations changed quickly

in Turkey after the outbreak of crisis in the U.S., and Figure 3.3 shows that the ratio of budget deficit to GDP increased to 5.3% which was the highest level seen since 2003. Table 3.1 also shows some major developments in GDP components during this period.

Figure 3.2: Consumer Confidence Index

Source: Central Bank of Republic of Turkey.

The Lucas Critique (LC; 1976), which made Prof. Robert E. Lucas a winner of the Nobel Prize in 1995 has been very influential in determination and application of macroeconomic policies and is based on the following notion "Given that the structure of an econometric model consists of optimal decision rules of economic agents, and that optimal decision rules vary systematically with changes in the structure of series relevant to the decision maker, it follows that any change in policy will systematically alter the structure of econometric models" (Lucas, 1976 p. 41). Lucas (1976) maintains that an econometric model is unstable and performs poorly in different time periods since a structural change (expectation-generating mechanism) and/or policy regime change over time. (Habibullah et al., 2001).

Table 3.1: Growth of Gross Domestic Product and its Components (%)[10].

	GDP Growth	Consumption Expenditure of Resident Households Growth	Share in GDP	Government Expenditure Growth	Share in GDP	Gross Fixed Capital Formation Growth	Share in GDP	Change in Stocks Growth	Share in GDP	Exports of Goods and Services Growth	Share in GDP	Imports of Goods and Services Growth	Share in GDP
2008Q1	7.01	5.72	71.6	5.52	9.1	7.33	24.9	-95.48	-0.1	12.95	25.5	14.03	30.9
2008Q2	2.63	0.62	68.8	-3.44	9.9	-2.04	25.1	-140.88	0.7	4.26	25.5	2.01	29.9
2008Q3	0.86	-0.35	65.7	2.65	9.0	-8.66	21.1	18.73	5.3	3.85	25.6	-3.84	26.7
2008Q4	-6.97	-6.67	69.9	2.83	12.7	-18.75	23.1	149.50	-6.0	-8.16	25.4	-24.89	25.1
2009Q1	-14.74	-10.23	75.3	5.26	11.2	-27.86	21.0	11790.91	-9.2	-11.06	26.6	-30.99	25.0
2009Q2	-7.77	-1.75	73.3	-0.14	10.7	-24.46	20.5	-517.15	-3.4	-10.78	24.6	-20.60	25.8
2009Q3	-2.77	-1.91	66.3	5.11	9.7	-18.21	17.8	1.76	5.6	-5.22	24.9	-11.66	24.3
2009Q4	5.86	4.98	69.3	18.20	14.2	-4.23	20.9	-32.94	-3.8	7.24	25.8	11.02	26.3
2010Q1	12.59	7.92	72.2	0.52	10.0	17.21	21.9	-94.85	-0.4	-0.85	23.4	21.99	27.1

Source: Central Bank of Republic of Turkey.

[10] Growth rates represent percentage changes in real GDP relative to the same quarter in previous year. Share in GDP represents the percentage share of the level of each variable in GDP

Figure 3.3: Budget Deficit as a Percentage of GDP

Source: Turkish Statistical Agency.

The LC analysis became particularly important for the aftermath of the 2008 crisis to assess the effects of consequent policy shifts to stimulate the economy. Although it is difficult to underestimate its importance, the Lucas Critique is limited in practice. Surprisingly, there has been no significant research based on the investigation of these effects through the argument of Lucas for Turkey during the GFC period, which this paper attempts to provide.

The main purpose of this article is to carry out the Superexogeneity test in order to examine the effect of fiscal policy on GDP in the Turkish economy for the Global Financial Crisis period.

This paper is structured as follows: Section II represents the theoretical and methodological framework of this study. Section III demonstrates the test results. Section IV provides the conclusion.

3.2. A THEORETICAL AND METHODOLOGICAL FRAMEWORK

According to the main argument of the Lucas Critique (Lucas, 1976), any change in economic policy will fundamentally alter the impact of the policy on the economy, because the economic agents form their expectations by considering the future, not the past.

The Lucas Critique is so momentous and influential, as to threaten econometric research unless it takes expectations into consideration, and it claims that when the policy changes, the consequences are not reliable.

Administering policies according to the econometric estimation of reduced form equations based on past data cannot provide useful information about the actual consequences of alternative policies since the parameters that are estimated therein are also subject to change.

In order to assess the validity of LC we specify GDP(y_t) as a function of government expenditure (x_t) in our regression framework. The Lucas Critique does not apply if x_t is superexogeneous with respect to y_t.

Superexogeneity testing procedure is used to assess the relevance of the LC (see Engle et al. (1983) for more comprehensive details of the methodology for testing superexogeneity). We define the joint, conditional and marginal distributions for superexogeneity testing following Engle et al. (1983) as:

$$F_k(k_t;\theta_t)=F_{y|x}(y_t|x_t;\lambda_{1t}).F_x(x_t;\lambda_{2t})$$

where $F_{y|x}$ and F_x are conditional and marginal models.

A variable x_t is said to be *weakly exogenous* for a set of parameters of interest Ψ (some functions of θ) in a conditional model of a variable y_t with parameters λ_1 with $k_t=(y_t, x_t)'$ if:

i) Ψ is a function of the parameters λ_{1t} alone;

ii) λ_{1t} and the parameters of the marginal model for x_t and λ_{2t} are variation free, which implies that there is no loss of information about from neglecting the marginal model (Caporale, 1996).

x_t is defined *as superexogenous* for Ψ if:

i) x_t is weakly exogenous for Ψ,

ii) changes in λ_{2t} do not cause changes in λ_{1t}. Here, a parameter is considered invariant for a class of interventions if it remains constant under these interventions. A model is invariant for such interventions if all its parameters are invariant (Engle et al, 1983, p. 284).

Engle et al. (1983) model the following linear regression equation, which is assumed as the joint distribution of y_t and x_t is conditional normal with the following conditional means:

$$E[y_t|I_t]=\mu_t^y \tag{3.1}$$

$$E[x_t|I_t]=\mu_t^x$$

and covariance matrix

$$\Sigma_t=\begin{bmatrix}\sigma^{yy} & \sigma^{yx}\\ \sigma^{xy} & \sigma^{xx}\end{bmatrix} \tag{3.2}$$

where x_t and y_t are conditional on the information set I_t that contains their past values, and the current and past values of other valid conditioning variables z_t. The conditional expectation of y_t on x_t can be expressed as:

$$E(y_t|x_t)=\lambda_t(x_t-\mu_t^x)+\mu_t^y \tag{3.3}$$

and

$$y_t\text{-E}(y_t|x_t)=\omega_t \tag{3.4}$$

Note that, λ_t is the regression coefficient of y_t on x_t which is equal to σ^{yx}/σ^{xx}; and ω_t is the conditional variance which equals to $\sigma^{yy}-(\sigma^{yx})^2/\sigma_t^{xx}$.

The conditional mean of y_t and x_t is considered in the following behavioral relationship as:

$$\mu_t^y=\beta\mu_t^x+z_t'\gamma \tag{3.5}$$

Combining Equations 3.3, 3.4 and 3.5 yields:

$$y_t=\beta x_t+z_t'\gamma+(\lambda_t\text{-}\beta)(\ x_t\text{-}\mu_t^x)+\omega_t \tag{3.6}$$

Equation (3.6) is employed for superexogeneity testing by examining the conditional and the marginal models. The conditional model for Δy_t and the marginal model for Δx_t are as follows:

$$\Delta y_t\ =\beta_0+\beta_1\Delta x_t+\beta_2\Delta C_t+\beta_3\Delta L_t+\varepsilon_t \tag{3.7}$$

$$\Delta x_t=\beta_0+\beta_1\Delta Tax_t+\beta_1\Delta I_t+\varepsilon_t \tag{3.8}$$

where C_t is the Capital, L_t is the Labour Participation Ratio, Tax_t is the total taxes and I_t is the import.

According to the Equation (3.6), Weak exogeneity of x_t for the parameters of interest requires that μ_t^x, σ_t^{xx}, and σ_t^{yx} do not enter the conditional model, which is satisfied if $\lambda_t=\beta$. This condition simply means that the resulting residuals from the marginal model must be insignificant in the conditional model.

As previously stated, the second condition of superexogeneity is satisfied under the existence of structural invariance which requires the nonsensitivity of the parameters of the conditional model for such interventions that induce structural changes in the marginal model parameters. Empirically, this condition can be tested by inserting a dummy variable in both conditional and marginal models. This

dummy represents the structural change or policy shifts. The structural invariance condition is satisfied, if this dummy variable, which captures the structural change and/or regime shifts, is significant in the marginal model and simultaneously insignificant in the conditional model. This method of testing the structural invariance has been used in many studies such as Hurn and Muscatelli, 1992; Engle and Hendry, 1993; Karunaratne, 1996; and Valadkhani, 1998.

The regime shift or structural change dummy variable in this study is defined as DUM_t, which demonstrates a notable increase in government spending and captures the GFC period for Turkey that takes the value of zero until the last quarter of 2008, and one otherwise.

3.3. DATA

The data set is quarterly and covers the period between 1990 and 2015. Description of the variables are as follows: GDP_t is the real gross domestic product with 1998 constant prices; GOV_t is the government spending; C_t is the capital; L_t is the labor participation ratio; I_t is the import; Tax_t is the total taxes, and DUM_t is the dummy variable that takes 0 between 1990Q1-2008Q3 and 0 otherwise.

All variables that are used in the empirical analysis are real, seasonally adjusted and, excluding Capital data, have been extracted from the Turkish Statistical Institute and TR Ministry of Finance Directorate General of Public Accounts. Capital data is not available in Turkey. As in Berlemann and Wesselhöft (2014), and Montanaro (2003), we obtain Capital Stock estimates by applying the Perpetual Inventory Method (PIM) to the regional investment series.

3.4. EMPIRICAL RESULTS

According to the augmented Dickey-Fuller (ADF) test results, all the variables are integrated of order one, i.e I(1). The ADF test results are reported in Appendix C.3.1.

The estimation results of the parsimonious dynamic conditional and marginal models by the application of the general-to-specific (GTS) methodology (Davidson et al., 1978; and Engle et al., 1983) are below. The optimum lag length is selected according to Akaike Information Criterion (AIC)[11] and the insignificant lags are eliminated according to the GTS approach. Johansen Cointegration Test Results are presented in Appendix C.3.2. The short-run dynamics are captured by the cointegrating vector as an error correction mechanism (ECM_{t-1}), which is significant as expected. The standard errors are in the box brackets. The models also pass the battery of diagnostic tests, and both the conditional and the marginal models appear to be stable and reveal mainly satisfactory diagnostic test results. We should note that the conditional model of GDP was estimated using HAC errors to account for the heteroscedasticity issue detected while testing. In other tests for both models, there were no signs of misspecification.

Conditional Model of *GDP*:

$$\Delta GDP_t = \underset{[97877]}{97664.2} - \underset{[0.025]}{0.089ECM_{t-1}} + \underset{[0.195]}{0.194\Delta GDP_{t-1}} + \underset{[0.073]}{0.084\Delta GOV_t} + \underset{[0.002]}{0.012\Delta C_t} - \underset{[97254.1]}{1418.9\Delta L_t} + \underset{[94336.8]}{422.05DUM_t} \quad (3.9)$$

$Adjusted\ R - squared = 0.232$

Serial Correlation F (2,53) = 0.469, Prob. F (2,53) = 0.627

Heteroscedasticity ARCH F (5,51) =5.398, Prob. F (5,51) = 0.0005

[11] According to AIC criterion, lag length is selected 5 for the Conditional Model, 1 for the Marginal Model.

Marginal Model of Government Expenditure:

$$\Delta GOV_t = -231335.3 - 0.705ECM_{t-1} - 0.079\Delta I_t + 0.052\Delta TAX_t + 667560.0DUM_t$$
$$[168681.1] \quad [0.117] \quad [0.049] \quad [0.193] \quad [250792.5] \tag{3.10}$$

$Adjusted\ R - squared = 0.387$
Serial Correlation F (2,56) = 0.161, Prob. F (2,56) = 0.851
Heteroscedasticity ARCH F (1,60) =2.78, Prob. F (1,60) = 0.10

Weak exogeneity and structural invariance test results are reported in Table 3.2. Both conditions of weak exogeneity and structural invariance appear to be satisfied indicating that government expenditure is superexogenous in relation to GDP. This implies that the policy regime shift for the period of the GFC in Turkey did not cause structural variance in government expenditure. The Lucas Critique which indicates that policy regime shifts imply structural breaks, appears to be refuted by these tests.

Table 3.2: Superexogeneity Test Results.

Test	Null Hypothesis	t-statistic
Weak exogeneity	$\varepsilon_t^{GOV} = 0$	1.57
Invariance:		
Marginal model	DUM = 0	2.661***
Conditional model	DUM = 0	0.004

Notes: *** indicates rejection of the null hypothesis at the 1% significance level.

3.5. CONCLUSION

As an emerging economy, Turkey was one of the hardest hit countries by the Global Financial Crisis through different channels. Starting from mid-2008, contraction of the economy affected many of the sectors in Turkey. This study provides an empirical analysis of the applicability of the LC examining the effects of fiscal policy by using the models of GDP and government expenditure for Turkey during the GFC period through the Superexogeneity test. Since the changes induced by the regime shift on the parameters of the marginal model do not alter the parameters of the conditional model, the structural invariance condition is satisfied. As a consequence, we did not find any empirical evidence of the Lucas Critique.

APPENDICES

Appendix C.3.1: Augmented Dickey-Fuller (ADF) Test Results

	Model	Level	
		ADF	Prob.
GDP_t	None	4.003	1.000
	Intercept	0.295	0.976
	Trend and intercept	-3.092	2.117
GOV_t	None	0.446	0.807
	Intercept	-1.357	0.597
	Trend and intercept	-3.667	0.032
C_t	None	0.641	0.852
	Intercept	-0.768	0.820
	Trend and intercept	-5.070	0.000
L_t	None	0.392	0.79
	Intercept	-0.765	0.821
	Trend and intercept	-1.473	0.827
I_t	None	1.466	0.963
	Intercept	-0.768	0.820
	Trend and intercept	-3.396	0.061
Tax_t	None	7.850	1.000
	Intercept	3.094	1.000
	Trend and intercept	-0.016	0.995

Appendix C.3.2: Johansen Cointegration Test

(c) Conditional Model for Money Demand				
	Eigenvalue	**Trace Statistic**	**0.05 Critical Value**	**Prob.****
None*	0.408	58.242	47.856	0.003
At most 1	0.215	27.768	29.797	0.084
(d) Marginal Model for Wealth				
	Eigenvalue	**Trace Statistic**	**0.05 Critical Value**	**Prob.****
None*	0.312	23.267	21.131	0.047
At most 1	0.163	11.040	14.264	0.152

Trace test indicates 1 cointegrating equation at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
** MacKinnon-Haug-Michelis (1999) p-values

CONCLUSION

Economists agree on the fact that the shocks to the financial system resulting from the global financial crisis were in many ways more complicated compared to those triggered by the Great Depression of the 1930s (Mishkin, 2011). Mishkin (2011) suggests that the aggressive post-crisis monetary policy was the best tool that could be implemented to mitigate the shocks, since the severity of the crisis in 2008 overwhelmed the ability of conventional monetary policy to counteract it. There are anomalies that were never observed before. This situation constitutes the very convenient setup for testing the Lucas Critique empirically.

Monetary shifts such as the QE policy carry high possibility to alter the structure of past-data-based economic models, as foreshadowed in the LC. If the LC holds, it is deceptive to focus solely on the past when economic consequences of such policies are determined, whereby expectations play a significant role in shaping them. Indeed, the management of expectations about future policy has become a central element of monetary theory with zero-bound policies, as highlighted in Mishkin (2011). The QE period represents an interesting and unique case of study. The period is crucial in the history of American economic policy-making in terms of the introduction of the QE, followed by the adoption of an inflation-targeting regime and re-stabilization of zero-bound interest rates by tapering original monetary easing. These policies would certainly have significant impact on unemployment and inflation, and the LC appears as an important element to explain these effects.

In the first two studies, we attempted to empirically investigate this issue for the U.S. through different prominent models during the period of the biggest policy changes after the 2008 crisis. Our findings comment on the validity of the LC during the period of unprecedented fundamental changes in monetary policy in the aftermath of the global financial crisis. Our empirical estimates reject the

condition of superexogeneity or parameter invariance, providing credibility to the LC. This is contrary to Hurn & Muscatelli (1992) which seems to be the only empirical paper that tests LC validity via SupEx methodology (in the example of the UK money demand). Indeed, the QE period represents the opportunity of radical policy shifts capturing massive liquidity provisions, purchases of both government and private assets, and dramatic expansion of the FED's balance sheet. This might be one explanation for our results that significantly support the validity of the LC in the model of money demand in the US. The use of a monetary policy based on QE1-2-3, overall, was an accomplishment and helpful to mitigate destructive shocks by the financial system. The FED was largely successful in administering and even manipulating the expectations - as suggested by Lucas - and made use of drastic change in the monetary policy regime to keep the growth rate, as well as the unemployment rate, at desirable levels despite the disastrous magnitude of the global financial crisis.

Our last study provides an empirical analysis of the applicability of the LC examining the effects of fiscal policy by using the models of GDP and government expenditure through the SupEx test for Turkey which was one of the hardest hit countries by the Global Financial Crisis through different channels.

In the context of our findings, what policymakers should consider is how to deal with those parameter inconstancies and therefore, with expectations. The instability of monetary models in the presence of structural breaks (following regime shifts) would mean considerable challenge for their use as a policy tool. However, Bernanke (2009) suggests that expectations, if effectively monitored, can rather be used as an additional tool to manage the implications of policy changes, especially in the environment of zero-bound policy. As the current FED chairman Yellen (2013) stressed, management of expectations has proven to be an immense asset in conducting post-crisis policies and minimizing policies' potential costs to the economy.

It is hoped to have wide areas of applications on the design of econometric research and monetary policies. We hope the impact of this thesis will be large and positive since all econometric models to represent the macroeconomic relations will be influenced and the policies to be put in action without the consideration of expectations will be reevaluated.

REFERENCES

Alogoskoufis, G. S., & Smith, R. (1991). The Phillips Curve, the persistence of inflation, and the Lucas critique: evidence from exchange-rate regimes. *The American Economic Review*, *81*(5), 1254–1275. https://doi.org/10.2307/2006916

Alzaabi, D. A. M. (2013). Where Does the WTO Stand in the Global Economic Recession. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.2267114

Bajo-Rubio, O., Díaz-Roldán, C., & Esteve, V. (2007). Change of regime and Phillips curve stability: The case of Spain, 1964-2002. *Journal of Policy Modeling*, *29*(3), 453–462. https://doi.org/10.1016/j.jpolmod.2006.06.017

Ball, L., & Mazumder, S. (2011). Inflation Dynamics and the Great Recession. *Brookings Papers on Economic Activity*, *42*(1 (Spring), 337–405. https://doi.org/DOI:

Ball, L., & Mazumder, S. (2014). *A Phillips Curve with Anchored Expectations and Short-Term Unemployment*. No.w20715 *National Bureau of Economic Research.* https://doi.org/10.3386/w20715

Banerjee, A., Hendry, D. F., & Mizon, G. E. (1996). The econometric analysis of economic policy. *Oxford Bulletin of Economics and Statistics*, 58(4), 573-600. Retrieved from http://eprints.soton.ac.uk/32883/

Belke, A. (2000). Partisan political business cycles in the German labour market ? Empirical tests in the light of the Lucas-critique. *Public Choice*, *104(3-4)*, 225–283.

Bernanke, B. S. (2009). Opening Remarks : The Economic Outlook and Monetary Policy. *Proceedings-Economic Policy Symposium-Jackson Hole*, 1–16.

Bernanke, B. S. (2012). The Fed - Monetary Policy since the Onset of the Crisis. Retrieved April 3, 2017, from https://www.federalreserve.gov/newsevents/speech/bernanke20120831a.htm

Bernanke, B. S., & Mishkin, F. S. (1997). *Inflation Targeting: A new framework for monetary policy?*. Journal of Economic perspectives, 11(2), 97-116.

Blanchard, O. J. (1984). *The Lucas critique and the Volcker deflation*.

Boug, P. (1999). The Demand for Labour and the Lucas Critique. Evidence from Norwegian Manufacturing. No. 256.

Brown, R. L., Durbin, J., & Evans, J. M. (1975). Techniques for testing the constancy of regression relationships over time. *Journal of the Royal Statistical Society*, 149–192.

Caballero, R. J. (2010). Macroeconomics after the Crisis: Time to Deal with the Pretense-of-Knowledge Syndrome. *Journal of Economic Perspectives*, *24*(4), 85–102. https://doi.org/10.1257/jep.24.4.85

Caporale, G. M. (1996). Testing for superexogeneity of wage equations. *Applied Economics*, *28*, 663–672.

Caporale, G. M., & Pittis, N. (2004). Robustness of the CUSUM and CUSUM-of-Squares Tests to Serial Correlation, Endogeneity and Lack of Structural Invariance. Some Monte Carlo Evidence. *Economics Series*.

Castelnuovo, E. (2008). Regime shifts and the stability of backward-looking Phillips curves in open economies. *Journal of International Money and Finance*, *27*(1), 40–53. https://doi.org/10.1016/j.jimonfin.2007.09.004

Chirinko, R. S. (1988). Business Tax Policy, The Lucas Critique, and Lessons from the 1980's. *American Economic Review*, *78*(2), 206–210. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=4505614&site=ehost-live&scope=site

Chow, G. C. (1960). Tests of equality between sets of coefficients in two linear regressions. *Econometrica*, 591–605.

Collard, F., Fève, P., & Langot, F. (2002). Structural Inference and the Lucas Critique. *Annals of Economics and Statistics / Annales d'Économie et de Statistique*, (67/68), 183–206. Retrieved from http://www.jstor.org/stable/20076347

Davidson, J. E., Hendry, D., Srba, F., & Yeo, S. (1978). Econometric Modelling of the Aggregate Time-Series Relationship Between Consumers' Expenditure and Income in the United Kingtom. *The Economic Journal*, *88*, 661–692.

Doan, T., Litterman, R., & Sims, C. A. (1984). Forecasting and conditional projection using realistic prior distributions. *Econometric Reviews*, *3*(1), 1–100.

Eggertsson, G. B., & Woodford, M. (2003). The Zero Bound on Interest Rates and Optimal Monetary Policy. *Brookings Papers on Economic Activity*, *34*(1), 139–235. https://doi.org/10.1353/eca.2003.0010

El-Shagi, M., & Giesen, S. (2013). Money and inflation: Consequences of the recent monetary policy. *Journal of Policy Modeling*, *4*(35), 520–537.

Engle, R. F., & Hendry, D. F. (1993). Testing superexogeneity and invariance in regression models. *Journal of Econometrics*, *56*(1–2), 119–139. https://doi.org/10.1016/0304-4076(93)90103-C

Engle, R. F., Hendry, D. F., & Richard, J.-F. (1983). Exogeneity. *Journal of Econometric Society*, 277–304.

Ericsson, N. R. (1992). Cointegration, exogeneity, and policy analysis: An overview. *Journal of Policy Modeling*, 14(3), 251-280. https://doi.org/10.1016/0161-8938(92)90001-S

Ericsson, N. R., Hendry, F. D., & Mizon, G. E. (1998). Exogeneity, Cointegration, and Economic Policy Analysis. *Journal of Business & Economic Staistics*, 16(4), 370-387.

Ericsson, N. R., & Irons, J. S. (1995). The Lucas critique in practice. *Macroeconometrics*, 263-324.

Estrella, A., & Fuhrer, J. C. (2003). Monetary policy shifts and the stability of monetary policy models. *The Review of Economics and Statistics*, *85*(1), 94–104.

Fair, R. C. (1987). Macroeconmetric models. *The New Palgrave: A Dictionary of Economics*, *3*, 269–273.

Faria, J. R., & León-Ledesma, M. A. (2005). Real exchange rate and employment performance in an open economy. *Research in Economics*, *59*(1), 67–80. https://doi.org/10.1016/j.rie.2004.12.005

Favero, C., & Hendry, F. D. (1992). Testing the Lucas critique: A review.

Econometric Reviews, *11*(3), 265–306. https://doi.org/10.1080/07474939208800238

Friedman, M. (1968). The role of monetary policy. *American Economic Review*, *58*, 1–17.

Fuhrer, J. (1997). The (Un)Importance of Forward-Looking Behavior in Price Specifications. *Journal of Money, Credit and Banking*, *29*(3), 338–350. https://doi.org/10.2307/2953698

Giersbergen, N., & Kiviet, J. F. (1996). No Title. *Oxford Bulletin of Economics and Statistics*, *58*(4), 631–656.

Gordon, R. (1982). Price inertia and policy ineffectiveness in the United States, 1890-1980. *Journal of Political Economy, 90(6),* 1087-1117.

Gordon, R. (2013). The Pillips Curve is Alive and Well: Inflation and the NAIRU During the Slow Recovery. *NBER Working Paper Series*, (19390), 1–57. https://doi.org/10.3386/w19390

Habibullah, M. S., Azali, M., & Baharumshah, A. Z. (2001). Money, income and the Lucas critique: the case for Malaysia. *Analisis*, *8*(1&2), 69–85. Retrieved from http://repo.uum.edu.my/431/

Harvey, A. C. (1981). Finite sample prediction and overdifferencing. *Journal of Time Series Analysis*, *2*(4), 221–232.

Hendry, D. F. (1995). *Dynamic Econometrics*. Oxford University Press on Demand.

Hurn, A. S., & Muscatelli, V. A. (1992). Testing Superexogeneity: the Demand for Broad Money in the Uk. *Oxford Bulletin of Economics and Statistics*, *54*(4), 543–556. https://doi.org/10.1111/j.1468-0084.1992.mp54004004.x

Jondeau, E., & Le Bihan, H. (2005). Testing for the New Keynesian Phillips curve. Additional international evidence. *Economic Modelling*, *22*(3), 521–550.

Judd, J. P., & Scadding, J. L. (1982). The Search for a Stable Money Demand Function: A Survey of the Post-1973 Literature. *Jounal of Economic Literature*, *20*(3), 993–1023. Retrieved from

http://www.jstor.org/stable/2724409?seq=1#page_scan_tab_contents

Karagiannis, S., Panagopoulos, Y., & Vlamis, P. (2010). Interest rate pass-through in Europe and the US: Monetary policy after the financial crisis. *Journal of Policy Modeling*, *32*(3), 323–338. https://doi.org/10.1016/j.jpolmod.2010.02.006

Karunaratne, N. D. (1996). Growth and trade dynamics under regime shifts in Australia. *Journal of Economic Studies*, *23*(2), 55–69.

Leeper, E. M., & Zha, T. (2003). Modest policy interventions. *Journal of Monetary Economics*, *50*(8), 1673–1700. https://doi.org/10.1016/j.jmoneco.2003.01.002

Lindé, J. (2001). Testing for the Lucas critique: A quantitative investigation. *American Economic Review*, *91*(4), 986–1005.

Litterman, R. (1984). Forecasting and Policy Analysis With Bayesian Vector Autoregression Models. *Quarterly Review*, *Fall*.

Liu, Y., & Morley, J. (2014). Structural evolution of the postwar U.S. economy. *Journal of Economic Dynamics and Control*, *42*, 50–68. https://doi.org/10.1016/j.jedc.2014.03.002

Lubik, T. A., & Surico, P. (2010). The lucas critique and the stability of empirical models. *Journal of Applied Econometrics*, *25*(1), 177–194. https://doi.org/10.1002/jae.1129

Lucas, R. E. (1976). Econometric policy evaluation: A Critique. *Carnegie-Rochester Conference Series on Public Policy*, *1*(1), 19–46. https://doi.org/10.1080/000368497327344

Mankiw, N. G., Miron, J. A., & Weil, D. A. (1987). *NBER Working Paper # 2124 The Adjustment of Expectations to a Change in Regime : A Study of the Founding of the Federal Reserve Dept . of Economics University of Michigan David A . Weil Dept . of Economics Harvard University Ann Arbor , MI 48109*.

Mazumder, S. (2011). The stability of the Phillips curve in India: Does the Lucas critique apply? *Journal of Asian Economics*, *22*(6), 528–539. https://doi.org/10.1016/j.asieco.2011.05.002

McCallum, B. (2005). Monetary Policy and the Term Structure of Interest Rates. *Federal Reserve Bnak of Richmond Economic Quarterly*, *91*, 1–21. Retrieved from http://linkinghub.elsevier.com/retrieve/pii/S1057521902000704

Miller, P. J., & Roberds, W. T. (1991). The Quantitative Significance of the Lucas Critique. *Journal of Business and Economic Statistics*, *9*(4), 361–387. https://doi.org/10.1080/07350015.1991.10509864

Mills, J. (1988). The Bayesian learning model of expectations as a solution to the Lucas critique: Some empirical evidence. *Mathematical and Computer Modelling*, *11*, 396-401. Retrieved from http://www.sciencedirect.com/science/article/pii/0895717788905225

Mishkin, F. S. (2001). *The transmission mechanism and the role of asset prices in monetary policy*. No. w8617. National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w8617

Mishkin, F. S. (2011). *Monetary policy strategy: lessons from the crisis.* No. w16755. National Bureau of Economic Research.

Oliveira, M. A., & Santos, C. (2007). Modelling the German Yield Curve and Testing the Lucas. *Applied Econometrics and International Development*, *7*(1).

Psaradakis, Z., & Sola, M. (1996). On the power of tests for superexogeneity structural invariance. *Journal of Econometrics*, *72*, 151–175.

Rai, V., & Suchanek, L. (2014). *The effect of the Federal Reserve's tapering announcements on Emerging Markets*. No. 2014-50. Bank of Canada Working Paper.

Rogoff, K. (2017). Monetary Policy in a Low Interest Rate World. *Journal of Policy Modeling*, 39(4), 63-679.

Rudebusch, G. (2005). Assessing the Lucas critique in monetary policy models. *Journal of Money, Credit and Banking*, *37*(2), 245–72. https://doi.org/10.1353/mcb.2005.0024

Santos, C. (2004). Extending the Superexogeneity Tests To Account for Unknow Break Dates. Mimeo. Retrieved from http://138.40.3.22/conferences/cfl/files/CFLPapersFinal/CarlosSantos.pdf

Sims, C. A. (1986). Are forecasting models usable for policy analysis? *Federal Reserve Bank of Minneapolis Quarterly Review*, *10*(1), 2–16.

Sims, C. A., Goldfeld, S. M., & Sachs, J. D. (1982). Policy analysis with econometric models. *Brookings Papers on Economic Activity*, *1*, 107–164.

Smith, R. (2009). EMU and the Lucas Critique. *Economic Modelling*, *26*(4), 744–750. https://doi.org/10.1016/j.econmod.2008.07.008

Stanley, T. D. (2000). An empirical critique of the Lucas critique. *The Journal of Socio-Economics*, *29*(1), 91–107.

Stock, J. H., & Watson, M. W. (1999). Forecasting Inflation. *Journal of Monetary Economics,* 44, 293-335.

Stock, J. H., & Watson, M. W. (2008). *Phillips Curve Inflation Forecasts.* No. w14322. National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w14322

Taylor, J. B. (1989). Monetary Policy and the Stability of Macroeconomic Relationships. *Journal of Applied Econometrics*, *4*(S), S161-78. https://doi.org/10.2307/2096598

Taylor, J. B. (2014). Rapid Growth or Stagnation: An Economic Policy Choice. *Journal of Policy Modeling*, *36*(4), 641–648.

Turner, P. (1997). The Phillips curve, parameter instability and the Lucas critique. *Applied Economics*, *29*(1), 7–10. https://doi.org/10.1080/000368497327344

Urbain, J.-P., & Lahaye, J. M. (1992). Structural Invariance and Super Exogeneity in Macroeconometric Model Building. *Cahiers Economiques de Bruxelles*, *134*, 209–234.

Valadkhani, A. (1998). Effect of government capital expenditure on GDP in the Iranian economy using superexogeneity testing. *Applied Economics Letters*, *5*(6), 361–364. https://doi.org/10.1080/135048598354726

Van Bergeijk, P., & Berk, J. M. (2001a). European monetary union, the term structure, and the Lucas critique. *Kyklos*, *54*(4), 547–556. Retrieved from http://www.scopus.com/inward/record.url?eid=2-s2.0-0035198278&partnerID=40&md5=b48fc5beb747f401266765ab060c2e78

Van Bergeijk, P., & Berk, J. M. (2001b). The Lucas Critique in Practice : An Empirical Investigation of the Impact of European Monetary Integration on the Term Structure.

Verick, S. ;, & Iyanatul Islam. (2010). *The Great Recession of 2008-2009: Causes, Consequences and Policy Responses*. Retrieved from http://hdl.handle.net/10419/36905

Yellen, J. (2013). *Panel Discussion on "Monetary Policy: Many Targets, Many Instruments. Where Do We Stand?": a speech at the" Rethinking Macro Policy II," a conference sponsored by the International Monetary Fund, Washington, DC, April 16, 2013*(No. 622).

Yildirim, M., & Korap, L. (2012). Testing the Lucas critique for the Turkish money demand function. *İktisat, İşletme ve Finans*, *27*(318), 57–82.