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Old Wine in a New Bottle: What Does Anticipated Economic Policy Do?

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Abstract

The aim of this study is to test the policy ineffectiveness proposition of rational expectations approach. According to this hypothesis, economic policies anticipated by economic units do not have any effect on business cycle; on the contrary, only the unanticipated policy would affect real output. With this aspect of it, the hypothesis becomes an empirical issue and an outcome that should be tested at least in the context of developing countries. To this end, the model in this study is developed within the public sector budget constraint based on that monetary and fiscal policies cannot be approached separately. The analytical solution of the model shows that both anticipated and unanticipated monetary and fiscal policies have effect on real output. Thus, the subject requires empirical proof; in other words, the theoretical finding should be supported empirically. According to estimation results, the policy ineffectiveness proposition of New Classical approach has not gained validity for the case of Turkey. The model tested with the data obtained from Turkey showed that both anticipated and unanticipated policy changes have influence on real output.

Key words: Anticipated policy, policy ineffectiveness, Turkey.

1. Introduction

In the macroeconomic researches conducted during 1980s, one of the

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subjects that had been widely studied on both theoretical and empirical basis was rational expectations hypothesis. Considered as a “revolution” by some authors (see Begg, 1985), this breakthrough was initiated by Robert Lucas with a study published in 1972 (Lucas, 1972), however it drew attention when Thomas Sargent and Neil Wallace used this approach in their studies on optimal monetary policy (Sargent &Wallace, 1975). One of the main results that this approach, called the New Classical Approach, had obtained is the policy ineffectiveness proposition. In literature, this proposition is shortly referred to as the LSW hypothesis.

The aim of this study is to test in the context of developing countries the policy ineffectiveness proposition which is obtained by the former studies based rational expectations approach. As Khan (1987) stated, it is a necessitation to test the rational expectations hypothesis in the context of developing countries. Tests on the rational expectations model in the context of developing countries are limited to certain Latin American countries such as Argentine, Brazil and Chile. On the other hand, the studies on this subject are in the form of cross-sectional data analyses rather than being specifically on one country (Khan & Knight, 1982). Turkey is an exemplary country that could be studied in this context. The first part of our study is for introducing what the policy ineffectiveness hypothesis is. To this end, first the distinction between anticipated and unanticipated policy is clarified through presenting the Lucas critique. In order to achieve this, the part in question avoids complex econometric notations as much as possible and simplifies the subject through the usage of graphical demonstrations where possible. The second part basically includes a specification of the rational expectations hypothesis considering the structural characteristics of a developing country. Following the specification, the model is solved analytically and discussed on theoretical grounds. In the third part, called the Estimation Results, econometric problems experienced during the estimation phase and estimation methods are presented and then the results obtained are considered from various aspects. Finally in the conclusion part, the conclusions obtained are summarized and some policy suggestions are made for decision makers.

2. Lucas Critique and Anticipated-Unanticipated Policy Distinction

In the last 30 years, macroeconometric models for countries have been developed, which, at first, were expressed with simple equations and became more and more complicated with each passing day. These econometric models have been and are still widely used for the estimation of economic aggregates and evaluation of economic policies. On the other hand, using these models, possible outcomes of a change in the economic policy were tried to be determined through simulations. However, Lucas (1972) asserts striking claims on the usefulness of traditional macroeconometric models. According to Lucas, if economic units are rational on their expectations, using traditional econometric models for the purpose of evaluating economic policies could lead to completely incorrect results[1]. In broad terms, rational expectations hypothesis assumes that economic units would make such estimations that would minimize estimation errors and that, while they do this, they are faced with a constraint on the available information. Hence, the fundamental assumption of the rational expectations hypothesis is to regard those economic units would endeavor to do the best they can in the estimation process. But this does not mean that economic units would not make any estimation error, it only means that such errors would not have a systematic component. Lucas' criticism for the traditional evaluations of economic policy is based on a fundamental principle of the rational expectations approach, which was roughly summarized above; the manner in which expectations are formed would change as the variable to be estimated changes. In this case, when there is a change in the economic policy, the manner in which expectations are formed would also change. Since expectations determine the manner of economic behavior, structural relationships that are proposed into econometric models would also change with expectations. As summarized, there are two important points that the

[1] In order to eliminate this problem, the new approach is to estimate the parameters of production and utility functions using first degree conditions. In these models, called as the intertemporal optimization, first degree conditions are satisfied with Euler equations. Barro (1990) constitutes a good example for the implementation of intertemporal optimization models, that is based on the New Classical rational expectations approach. Razin et al. (1989) could be perused for an application of the same concept with non-classical rational expectations approach.

Lucas Critique presents; the first one is that traditional econometric models cannot be used for the evaluation of the effects of a change in the economic policy. The second point that the Lucas Critique presents is even more important: Since the influence that economic policy would create depends on the expectations of the public about this policy, expectations of economic units would also determine the attitude that they would assume in relation to the change in the economic policy being followed. In literature, this distinction on economic policies is called the anticipated – unanticipated policy distinction.

In order to better see the effects of the aforementioned distinction, the analysis could be enhanced with a simple example. Consider a surprise policy implementation that economic units did not expect. In Figure 1 below, the effects of such unanticipated (surprise) policy change are addressed. Prior to the policy change, the price level expectation of economic units, $E(P_1)$, creates an aggregate supply curve, AS_1. Initial aggregate demand curve AD_1 intersects the aggregate supply curve at point X, hence total product is Y_n. On the other hand, at point X, the actual (P_1) and anticipated ($E(P_1)$) price levels are equal. Since the point X is also located on the long run aggregate supply curve, there is no tendency to shift in the aggregate supply. In this setting, assume that the management finds the unemployment rate to be too high and decides to follow an expansionary monetary policy contrary to what the economic units expect and the central bank buys bonds on a large scale in the open market. In this case, with the increase in money supply, the aggregate demand curve would shift up to AD_2. Since this increase in demand was not expected, the anticipated price level will remain the same and consequently, the aggregate supply curve would not move. In this case, the new equilibrium will be formed at point Z where curves AD_2 and AS_1 intersect. The change in the economic policy proved effective, output raised up to point Y_2 and prices increased to the level P_2.

If economic units know that the management had acted similarly in previous periods and expect that the central bank would buy bonds in the open market, the expansionary monetary policy would be an anticipated

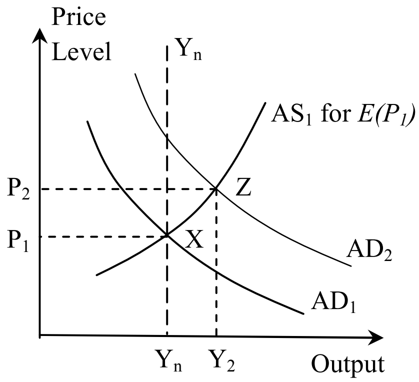

Fig. 1 Effects of Unanticipated Policy

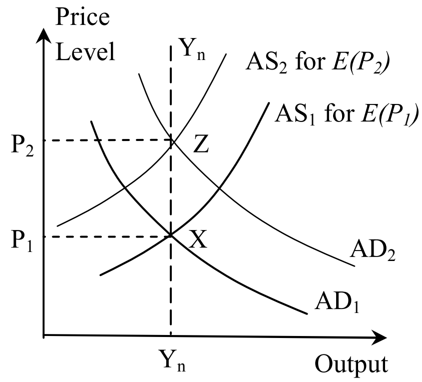

Fig. 2 Effects of Anticipated Policy

policy. Let's try to explain the results of such an anticipated policy with the help of Figure 2. Because economic units are rational at their expectations, employees expect that, as a result of the expansionary monetary policy, the aggregate demand curve would shift upward and price level would be P_2. Unions would demand higher wages in order to keep the real wages at the same level when prices increase. This will move the curve AS_1 to AS_2 and the new equilibrium will be on point Z where curves AD_2 and AS_2 intersect. As can be seen, without a change in output, actual price level increased to P_2. In this case, the other hypothesis that the New Classical model proposes; in case a change in economic policy is an anticipated change by economic units, it would have no effect on real business cycle; only the unanticipated policy changes would create the desired effect. This result obtained by the New Classical model is called the policy ineffectiveness (Mishkin, 1990).

The first empirical evidence for policy ineffectiveness was obtained by Barro (1989a). In this study, changes in money supply are divided into two components as anticipated and unanticipated changes. Anticipated changes in money supply are estimated using the "money supply reaction function" developed for the central bank. The empirical method established in the study was implemented by a large number of researchers and empirical evidence for policy ineffectiveness was presented. These studies include

Taylor (1989), Attfield – Duck (1983), and Darrat (1988). There are, on the other hand, researches that disprove the same hypothesis on empirical grounds (Mishkin, 1983). For this reason, the validity of policy ineffectiveness hypothesis has become an empirical issue.

2. Specification of the Model

The model considered in this study is based on a version of Sargent – Wallace model which is developed by McCallum (1980). However, the model that is considered here differs from the McCallum model by including a different money supply mechanism. In the aforementioned studies, the money supply mechanism was based on the feedback rule that is composed of a systematic component that includes the money supply of the previous period, income and a non-systematic random component. In authors opinion, in developing countries, it is not possible to separate the decisions of monetary authorities from the decisions of public authorities through basing monetary authority decisions on the feedback rule. In other words, in developing countries, considering that monetary and fiscal policies cannot be approached separately and these policies are interdependent (Razin, 1989), it would be more suitable to evaluate the decisions of monetary authorities under the constraints of public sector. The following budget constraint defined for public sector would form a basis for the model:

$$G_t = T_t + \Delta D_t + \Delta B_t \tag{1}$$

where G is total public expenditures, T is tax income, ΔD is change in public sector debt, ΔB is change in monetary base. When M represents money supply and m represents money multiplier, the money supply determination mechanism would be as follows:

$$M = m \times B \tag{2}$$

Utilizing Equations (1) and (2), money supply would be integrated into model as a behavioral equation (logarithmically) as:

$$logM_t = \alpha_0 + \alpha_1 logG_t + \alpha_2 logT_t + \alpha_3 logD_t + \alpha_4 logD_{t-1} + \alpha_5 logB_{t-1} + \varepsilon_1 \tag{3}$$

where ε is the white noise term. It can be accepted that that real government spending is a function of real output and previous period's government spending (Razin, 1989). Therefore, it is possible to express real public expenditures as follows:

$$logG_t = \beta_0 + \beta_1[logG_{t-1} - logP_{t-1}] + \beta_2 logy_{t-1} + \beta_3 logP_{t-1} + \varepsilon_2 \tag{4}$$

Assuming that main tax revenue of the government is from institutions and people, it is possible to accept that public sector real tax revenue is determided by the current and previous period's real output. Therefore, real tax income is

$$logT_t = \pi_0 + \pi_1 logy_t + \pi_2 logy_{t-1} + \pi_3 logP_t + \varepsilon_3 \tag{5}$$

At this point, the *IS*, *LM*, and *Lucas* supply functions can be included into the model. The *IS* function will be integrated in the model as

$$logy_t = \delta_0 + \delta_1[log(1+r)_t - E_{t-1}(logP_{t+1} - logP_t)] + \delta_2 logG_t + \delta_3 logT_t + (\delta_2 - \delta_3)logP_t + \varepsilon_4 \tag{6}$$

LM function as

$$logM_t = \sigma_0 + \sigma_1 logy_t + \sigma_2 log(1+r)_t + logP_t + \varepsilon_5 \tag{7}$$

and *Lucas* supply function as

$$logy_t = \theta_0 + \theta_1[logP_t - E_{t-1}(logP_t)] + \theta_2 logy_{t-1} + \varepsilon_6 \tag{8}$$

where r is nominal interest rate and $E_{t-1}(X_{t+j})$ refers to the mathematical expectation regarding the variable X_{t+j} *(for* $j=0,1,\ldots,n$*)* when all available data set as of period "*t-1*" is given. In this case, it is possible to write down the following relation that is valid in this model and that can be regarded as the common form of representing the rational expectations hypothesis:

$$(X^e)_{t+1} = E_{t-1}[X_{t+1} \mid \Omega_{t-1}]$$

In the above equation, the magnitude expressed as X^e represents the expectation of economic unit on the variable X and Ω represents the available data set at the end of the period "*t-1*". In this case, economic units have sufficient information about the operation of the system and hence, the following assumption can be made; when individuals make a prediction on economic issues, they act as if they have acquired the reduced forms of each endogenous variable that is included in the above model, and using these forms, they determine what their expectations on endogenous variables would be. For this reason, in order to complete the available data set at period "*t-1*", the above model should include a behavioral equation related to price level. At this point, the Barro approach (1989b) is adopted and the behavioral equation related to price level is incorporated into the model using the real money demand function:

$$\begin{gathered} logP_t = logM_t - \mu_0 - \mu_1 logy_t - \mu_2 log(1+r)_t + \varepsilon_i \\ (i = 1, \ldots, 6)\ i\c{c}in \end{gathered} \quad (9)$$

Now, it is time to determine the variables that influence the equilibrium level for real output (y_t). In this part of the study, the reduced form equations that were derived, without going into the manipulations regarding the derivation. Since the solution of the model constitutes a significant constraint with regards to theoretical discussions, the solution method is presented in Appendix at the end of the study. The reduced form real product equation derived as mentioned is as follows:

$$\begin{gathered} logy_t = \Gamma_0 + \Gamma_1(logG_{t-1} - logP_{t-1}) + \Gamma_2 logy_{t-1} + \Gamma_3 logP_t \\ + \Gamma_4 E_{t-1}[logP_{t+1} - logP_t] \\ + \Gamma_5 logD_t + \Gamma_6 logD_{t-1} + \Gamma_7 logB_{t-1} + \varepsilon_7 \end{gathered} \quad (10)$$

where

$$\Gamma_0 = \frac{\delta_0\sigma_2 - \delta_1\sigma_0 + \delta_1\alpha_0 + \beta_0(\delta_1\alpha_1 + \delta_2\sigma_2) + \pi_0(\delta_1\alpha_2 + \delta_3\alpha_2)}{\delta_1\sigma_1 + \sigma_2 - \pi_1(\delta_1\alpha_2 - \delta_3\sigma_2)}$$

$$\Gamma_1 = \frac{\beta_1(\delta_1\alpha_1 + \delta_2\sigma_2)}{\delta_1\sigma_1 + \sigma_2 - \pi_1(\delta_1\alpha_2 - \delta_3\sigma_2)}$$

$$\Gamma_2 = \frac{\beta_2(\delta_1\alpha_1 + \delta_2\sigma_2) + \pi_2(\delta_1\alpha_2 - \delta_3\alpha_2)}{\delta_1\sigma_1 + \sigma_2 - \pi_1(\delta_1\alpha_2 - \delta_3\sigma_2)}$$

$$\Gamma_3 = \frac{\delta_1(\alpha_1 + \alpha_2 - 1)}{\delta_1\sigma_1 + \sigma_2 - \pi_1(\delta_1\alpha_2 - \delta_3\sigma_2)}$$

$$\Gamma_4 = \frac{-\delta_1\sigma_2}{\delta_1\sigma_1 + \sigma_2 - \pi_1(\delta_1\alpha_2 - \delta_3\sigma_2)}$$

$$\Gamma_5 = \frac{\delta_1\alpha_3}{\delta_1\sigma_1 + \sigma_2 - \pi_1(\delta_1\alpha_2 - \delta_3\sigma_2)}$$

$$\Gamma_6 = \frac{\delta_1\alpha_4}{\delta_1\sigma_1 + \sigma_2 - \pi_1(\delta_1\alpha_2 - \delta_3\sigma_2)}$$

$$\Gamma_7 = \frac{\delta_1\alpha_5}{\delta_1\sigma_1 + \sigma_2 - \pi_1(\delta_1\alpha_2 - \delta_3\sigma_2)}$$

$$\varepsilon_7 = \frac{\delta_1\varepsilon_1 + (\delta_1\alpha_1 + \delta_2\sigma_2)\varepsilon_2 + (\delta_1\alpha_2 - \delta_3\sigma_2)\varepsilon_3 + \sigma_2\varepsilon_4 - \delta_1\varepsilon_5}{\delta_1\sigma_1 + \sigma_2 - \pi_1(\delta_1\alpha_2 - \delta_3\sigma_2)}$$

Furthermore, price level estimation errors of economic units are found as follows:

$$logP_t - E_{t-1}logP_t = \frac{1}{\theta_1 - \Gamma_3}(\varepsilon_7\varepsilon_6) \tag{11}$$

Substituting this equation into *Lucas* supply function, the final form of output is obtained as:

$$logy_t = \theta_0 + \theta_2 \, logy_{t-1} + \frac{1}{\theta_1 - \Gamma_3}[\theta_0 \varepsilon_7 - \Gamma_3 \varepsilon_6] \qquad (12)$$

As can be seen, the parameters Γ_3 and ε_7, together with the parameters θ_0, θ_1, θ_2 and ε_6 that were given in the first specification of the equation, are among the parameters that influence output. As can be recognized from Equation 10, both of the parameters Γ_3 and ε_7 include the parameters α_1 and α_2 that are related to monetary policy and parameter π_1 that is related to fiscal policy. In this case, total product is not considered independently from monetary and fiscal policies, and both policies are theoretically influential on changes in total output. In other words, the "policy ineffectiveness" hypothesis laid out in the first part loses validity in theoretical sense within the framework of the model considered. The issue becomes an empirical issue at this point and the parameters in question are required to be estimated and investigated for statistical validity. If these parameters that include monetary and fiscal policy variables gain statistical validity, the theoretical finding would be verified and it would be concluded that the policy ineffectiveness hypothesis is not confirmed in the context of developing countries.

3. Estimation Results

The consideration above did not make a distinction whether a change in the economic policy followed was or was not expected by economic units. In order to overcome this problem, the model will be estimated as whole, fitted values and residuals will be used as anticipated and unanticipated policy variables, respectively. By using time series formed in this way, the final form output equation in Equation 11 will be estimated so that it will include anticipated and unanticipated policy variables. Since there is no priori information on the lag structure of the final form output equation, it will be specified once again as follows and the proper lag structure will be determined using the Akiake Information Criterion. The final form real output equation can therefore be shown as follows:

$$\begin{aligned} logy_t = \psi_0 + \psi_1\, logy_{t-1} + \psi_2(L)\, {}_aT_{t-i} + \psi_3(L)\, {}_aM_{t-i} \\ + \psi_4(L)\, {}_uG_{t-i} + \psi_5(L)\, {}_uT_{t-i} + \psi_6(L)\, {}_uM_{t-i} + \xi \end{aligned} \quad (13)$$

In this equation, the prefix "*a*" represents anticipated policy and prefix "*u*" represents unanticipated policy. Moreover, *L* is polynomial lag operator and ξ is white noise term. Before explaining estimation results, it is required to illuminate an aspect that draws attention in Equation 13. This equation does not include the variable related to anticipated public expenditures (${}_aG_t$), but does include the variable related to unanticipated public expenditures (${}_uG_t$). The reason is that there isn't any parameter (β_i) in equation (4) that represents anticipated public expenditures; however the white noise term that represents unanticipated public expenditure (which is ε_2 in equation (4)) is contained by ε_7 in the final form output equation.

The model developed in previous parts is estimated in the light of the explanations above using quarterly data for the period 2002:01 – 2016:02 obtained from Turkey. The three-stage least squares (3SLS) method is used in the estimation of the model composed of Equations 3, 4, 5, and 9. Since each equation in the system of equations is overidentified, 3SLS method would yield more effective results compared to LIML, 2SLS and OLS methods (Hausman, 1983). Estimation results are given in Table 1.

The 3SLS results obtained appear to be quite satisfactory. Coefficients of lagged real output in the equation related to public expenditures and of current real output in the equation related to taxes are statistically zero at 1 percent level of significance. Furthermore, the coefficient in the first variable has the expected sign, while the coefficient in the equation related to taxes has the opposite sign. The same is true for current and lagged variables related to public debt in the money supply equation. As a result of this system of four equations, values determined in relation to endogenous variables form the series of anticipated policy variables, and residuals form

Table 1
3SLS Estimation Results

Independent Variable	Dependent Variable							
	$\log(G_t)$	t-stat	$\log(T_t)$	t-stat	$\log(M_t)$	t-stat	$\log(P_t)$	t-stat
Constant	0.023	0.041	-1.371	6.421	-0.214	1.819	1.019	3.727
$\log(y_t)$			-0.965	1.419			0.914	2.401
$\log(P_t)$	0.977	6.811	0.812	4.665				
$\log(G_t)$					0.395	2.891		
$\log(T_t)$					-0.472	3.884		
$\log(D_t)$					0.003	0.115		
$\log(M_t)$							0.919	6.255
$\log(1+r_t)$							0.021	0.051
$\log(y_{t-1})$	0.319	1.218	2.624	2.753				
$\log(D_{t-1})$					-0.011	0.069		
$\log(B_{t-1})$					0.833	4.719		
$\log(G_{t-1}-P_{t-1})$	0.753	3.148						
$AdjR^2$	0.914		0.828		0.873		0.712	
SER	0.112		0.202		0.100		0.153	
SSR	0.212		0.697		0.150		0.420	
RCMD	1.115E-8							

Note: SER, SSR and RCMD refer to standard error of the estimation, sum of squared residuals and determinant value of residual covariance matrix, respectively.

the series of unanticipated monetary variables. Time series created in this way are used in the estimation of final form real ouput equation using OLS and the results are summarized in Table 2.

Table 2
Reduced Form Real Output Estimation

Variable	Coefficient (ψ_i)	t-statistic	Marginal Significance
Constant	-0.143	2.713	0.033
y_{t-1}	0.911	5.679	0.000
${}_aT_t$	-0.120	3.814	0.009
${}_aM_{t-1}$	0.215	3.411	0.012
${}_uG_t$	0.009	0.457	0.721
${}_uT_t$	0.214	2.824	0.031
${}_uM_{t-1}$	0.335	2.746	0.032
$AdjR^2$	0.914	Durbin-h	0.444
SER	0.021	Box-Pierce	5.747
SSR	0.014	LM	0.315

Since models of rational expectations are oversensitive to autocorrelation problem, the Durbin-h, Box-Pierce, and LM autocorrelation tests in the above table were calculated separately. All the test statistics show that such a problem does not exist. As estimation results immediately showed, the variables ${}_aT$ and ${}_aM$ that represent anticipated tax and monetary policy are statistically significant at a level of 1 percent. Except unanticipated public expenditure variable (${}_uG$), other unanticipated policy variables (${}_uT$ and ${}_uM$) gained statistical validity at a level of 5 percent. In this case, the hypothesis, that is an important one in the Lucas critique and which states that anticipated economic policy changes would not have an influence on real income and that only unanticipated policy changes that could be considered as surprise for economic units would influence real product, is not verified for Turkey. The empirical results obtained show that both anticipated and unanticipated changes in monetary and fiscal policies are influential on real output.

4. Conclusion

One of the hypotheses proposed by the New Classical approach is the hypothesis of policy ineffectiveness proposition. According to this hypothesis, economic policies anticipated by economic units do not have any effect on business cycle; on the contrary, only the unanticipated policy would affect real output. With this aspect of it, the hypothesis becomes an empirical issue and an outcome that should be tested at least in the context of developing countries. To this end, the model in our study is developed within the public sector budget constraint based on that monetary and fiscal policies cannot be approached separately. The analytical solution of the model shows that both anticipated and unanticipated monetary and fiscal policies have effect on real output. These effects work through money supply, government expenditures and taxes on both anticipated and unanticipated grounds (with the exemption of anticipated government expenditures). Transmission mechanism of these policy changes to the real output works via primarily price level and interest rate. Thus, the subject requires empirical proof; in other words, the theoretical finding should be supported empirically.

According to estimation results obtained, the hypothesis of New

Classical approach summarized above has not gained validity for the case of Turkey. The model tested with the data obtained from Turkey showed that both anticipated and unanticipated policy changes have influence on real output.

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Appendix

Obtaining Reduced Form Equations

To eliminate the interest rate from the model first solve Equation 7 in terms of *r* to get

$$log(1+r)_t = \frac{1}{\sigma_2}[(-\sigma_0) - \sigma_1 logy_t - logP_t + logM_t - \varepsilon_5]$$

Substituting the last equation into Equation 6 and rearranging terms to obtain

$$\begin{aligned}\delta_2 logy_t = \sigma_2\delta_0 - \delta_1\sigma_0 - \delta_1\sigma_1 logy_t + \delta_1 logM_t - \delta_1\varepsilon_5 \\ - \sigma_2\delta_1 E_{t-1}[logP_{t+1} - logP_t] + \sigma_2\delta_2 logG_t \\ - \delta_3\sigma_2 logT_t + \sigma_2\varepsilon_4 - [\delta_1 + \sigma_2(\delta_2 - \delta_3)]logP_t\end{aligned}$$

Solving the last equation for y_t generates

$$\begin{aligned}logy_t = \frac{1}{\delta_1\sigma_1 + \sigma_2}\{[\delta_0\sigma_2 - \delta_1\sigma_0] + \delta_1 logM_t \\ - [\delta_1 + \sigma_2(\delta_2 - \delta_3)]logP_t \\ - \delta_1\sigma_2 E_{t-1}(logP_{t+1} - logP_t) + \delta_2\sigma_2 logG_t \\ - \delta_3\sigma_2 logT_t + \sigma_2\varepsilon_4 - \delta_1\varepsilon_5\}\end{aligned}$$

If the Equations 3, 4 and 5 are substituted in the text the above equation becomes

$$
\begin{aligned}
logy_t = \frac{1}{\sigma_2 + \delta_1\sigma_1}\{ & \sigma_2\delta_0 - \delta_1\sigma_0 + \delta_1\alpha_0 + \delta_1\alpha_1\beta_0 \\
& + \delta_1\alpha_1\beta_1(logG_{t-1} - logP_{t-1}) + \delta_1\alpha_1\beta_2 logy_{t-1} \\
& + \delta_1\alpha_1 logP_t + \delta_1\alpha_1\varepsilon_2 + \delta_1\alpha_2\pi_0 + \delta_1\alpha_2\pi_1 logy_t \\
& + \delta_1\alpha_2\pi_2 logy_{t-1}\delta_1\alpha_2 logP_t + \delta_1\alpha_2\varepsilon_3 + \delta_1\alpha_3 logD_t \\
& + \delta_1\alpha_4 logD_{t-1} + \delta_1\alpha_5 logB_{t-1} + \delta_1\varepsilon_1 + \sigma_2\delta_2\beta_0 \\
& + \sigma_2\delta_2\beta_1(logG_{t-1} - logP_{t-1}) + \sigma_2\delta_2\beta_2 logy_{t-1} \\
& + \sigma_2\delta_2 logP_t + \sigma_2\delta_2\varepsilon_2 - \sigma_2\delta_3\pi_0 - \sigma_2\delta_3\pi_1 logy_t \\
& - \sigma_2\delta_3\pi_2 logy_{t-1} - \sigma_2\delta_3 logP_t - \sigma_2\delta_3\varepsilon_3 \\
& - [\delta_1 + \sigma_2(\delta_2 - \delta_3)]logP_t \\
& - \sigma_2\delta_1 E_{t-1}(logP_{t+1} - logP_t) - \delta_1\varepsilon_5 + \sigma_2\varepsilon_4\}
\end{aligned}
$$

Gathering the terms with the same parameters and rearranging gives the following:

$$
\begin{aligned}
(\sigma_2 + \delta_1\sigma_1)logy_t - [\pi_1(\delta_1\alpha_2 - \sigma_2\delta_3)]logy_t \\
= \sigma_2\delta_2 - \delta_1\sigma_0 + \delta_1\alpha_0 + \beta_0(\delta_1\alpha_1 + \sigma_2\delta_2) \\
+ \pi_0(\delta_1\alpha_2 - \sigma_2\delta_3) \\
+ [\beta_1(\delta_1\alpha_1 + \sigma_2\delta_2)](logG_{t-1} - logP_{t-1}) \\
+ [\beta_2(\delta_1\alpha_1 + \sigma_2\delta_2) + \pi_2(\delta_1\alpha_2 - \sigma_2\delta_3)]logy_{t-1} \\
+ [\delta_1(\alpha_1 + \alpha_2 - 1)]logP_t \\
- \sigma_2\delta_1 E_{t-1}(logP_{t+1} - logP_t) + \delta_1\alpha_3 logD_t \\
+ \delta_1\alpha_4 logD_{t-1} + \delta_1\alpha_5 logB_{t-1} + \sigma_2\varepsilon_4 - \delta_1\varepsilon_5 + \delta_1\varepsilon_1 \\
+ (\delta_1\alpha_1 + \sigma_2\delta_2)\varepsilon_2 + (\delta_1\alpha_2 + \sigma_2\delta_3)\varepsilon_3
\end{aligned}
$$

In this equation if it is defined

$$
\Gamma_0 = \frac{\delta_0\sigma_2 - \delta_1\sigma_0 + \delta_1\alpha_0 + \beta_0(\delta_1\alpha_1 + \delta_2\sigma_2) + \pi_0(\delta_1\alpha_2 + \delta_3\alpha_2)}{\delta_1\sigma_1 + \sigma_2 - \pi_1(\delta_1\alpha_2 - \delta_3\sigma_2)}
$$

$$
\Gamma_1 = \frac{\beta_1(\delta_1\alpha_1 + \delta_2\sigma_2)}{\delta_1\sigma_1 + \sigma_2 - \pi_1(\delta_1\alpha_2 - \delta_3\sigma_2)}
$$

$$
\Gamma_2 = \frac{\beta_2(\delta_1\alpha_1 + \delta_2\sigma_2) + \pi_2(\delta_1\alpha_2 - \delta_3\alpha_2)}{\delta_1\sigma_1 + \sigma_2 - \pi_1(\delta_1\alpha_2 - \delta_3\sigma_2)}
$$

$$\Gamma_3 = \frac{\delta_1(\alpha_1 + \alpha_2 - 1)}{\delta_1\sigma_1 + \sigma_2 - \pi_1(\delta_1\alpha_2 - \delta_3\sigma_2)}$$

$$\Gamma_4 = \frac{-\delta_1\sigma_2}{\delta_1\sigma_1 + \sigma_2 - \pi_1(\delta_1\alpha_2 - \delta_3\sigma_2)}$$

$$\Gamma_5 = \frac{\delta_1\alpha_3}{\delta_1\sigma_1 + \sigma_2 - \pi_1(\delta_1\alpha_2 - \delta_3\sigma_2)}$$

$$\Gamma_6 = \frac{\delta_1\alpha_4}{\delta_1\sigma_1 + \sigma_2 - \pi_1(\delta_1\alpha_2 - \delta_3\sigma_2)}$$

$$\Gamma_7 = \frac{\delta_1\alpha_5}{\delta_1\sigma_1 + \sigma_2 - \pi_1(\delta_1\alpha_2 - \delta_3\sigma_2)}$$

$$\varepsilon_7 = \frac{\delta_1\varepsilon_1 + (\delta_1\alpha_1 + \delta_2\sigma_2)\varepsilon_2 + (\delta_1\alpha_2 - \delta_3\sigma_2)\varepsilon_3 + \sigma_2\varepsilon_4 - \delta_1\varepsilon_5}{\delta_1\sigma_1 + \sigma_2 - \pi_1(\delta_1\alpha_2 - \delta_3\sigma_2)}$$

and substitute into original equation the Equation 10 is obtained in the text

$$\begin{aligned} logy_t = \Gamma_0 + \Gamma_1(logG_{t-1} - logP_{t-1}) + \Gamma_2 logy_{t-1} + \Gamma_3 logP_t \\ + \Gamma_4 E_{t-1}[logP_{t+1} - logP_t] \\ + \Gamma_5 logD_t + \Gamma_6 logD_{t-1} + \Gamma_7 logB_{t-1} + \varepsilon_7 \end{aligned}$$

Substituting the last equation into Lucas Supply Function and rearranging terms yield

$$\begin{aligned} \theta_1 logP_t - \Gamma_3 logP_t \\ = \Gamma_0 + \Gamma_1(logG_{t-1} - logP_{t-1}) + \Gamma_2 logy_{t-1} \\ + \Gamma_4 E_{t-1}(logP_{t+1} - logP_t) + \Gamma_5 logD_t + \Gamma_6 logD_{t-1} \\ + \Gamma_7 logB_{t-1} + \varepsilon_7 - \theta_0 + \theta_1 E_{t-1} logP_t - \theta_2 logy_{t-1} \\ - \varepsilon_6 \end{aligned}$$

Solving this equation for P_t gives

$$\begin{aligned} logP_t = \frac{1}{\theta_1 - \Gamma_3}\{(\Gamma_0 - \theta_0) + \Gamma_1(logG_{t-1} - logP_{t-1}) \\ + (\Gamma_2 - \theta_2)logy_{t-1} + \Gamma_4 E_{t-1}(logP_{t+1} - logP_t) \\ + \Gamma_5 logD_t + \Gamma_6 logD_{t-1} + \Gamma_7 logB_{t-1} + \varepsilon_7 - \varepsilon_6\} \end{aligned}$$

Taking the expectation E_{t-1} of the last equation, since $E_{t-1}(\varepsilon_7) = 0$ and $E_{t-1}(\varepsilon_6) = 0$, generates

$$E_{t-1}logP_t = \frac{1}{\theta_1 - \Gamma_3}\{(\Gamma_0 - \theta_0) + E_{t-1}\Gamma_1(logG_{t-1} - logP_{t-1}) + E_{t-1}(\Gamma_2 - \theta_2)logy_{t-1} + E_{t-2}[\Gamma_4 E_{t-1}(logP_{t+1} - logP_t)] + E_{t-1}\Gamma_5 logD_t + E_{t-1}\Gamma_6 logD_{t-1} + E_{t-1}\Gamma_7 logB_{t-1}\}$$

If the last expectation equation is subtracted from the price level equation and rearrange terms price level forecast error equation is obtained as:

$$logP_t - E_{t-1}logP_t = \frac{1}{\theta_1 - \Gamma_3}[\varepsilon_7 - \varepsilon_6]$$

Substituting the price level forecast error equation into Lucas Supply Function and rearranging give

$$logy_t = \theta_0 + \theta_2 logy_{t-1} + \frac{\theta_1\varepsilon_7 - \Gamma_3\varepsilon_6}{\theta_1\Gamma_3}$$

And finally the final reduced form of real activity is obtained as:

$$logy_t = \theta_0 + \theta_2 logy_{t-1} + \frac{1}{\theta_1 \quad \Gamma_3}[\theta_1\varepsilon_7 - \Gamma_3\varepsilon_6]$$