Quantity Theory of Money, Central Bank Independence, and Inflation ———A Panel Data Approach———

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Abstract

One of the most important theories to explain the long run rate of inflation is the quantity theory of money. However, most studies which examine the relationship between the rate of inflation and the degree of central bank independence (CBI) did not take into account of the quantity theory of money explicitly. In this paper, we first regress the rate of inflation on the country fixed effect, the growth rate of output, that of money stock, and world common shock using cross-country time-series panel regression technique. We regard the estimated fixed effect of each country obtained in this way as the country specific long run rate of inflation, since they are the average rate of inflation which cannot be explained by the framework of the quantity theory of money. The estimated fixed effect and CBI of each country are negatively correlated, hence our results are consistent with the results obtained from the previous studies.

Key Words :Central Bank Independence, Panel Data
JEL Classification: E51, E58, C33

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１. Introduction

Regarding an independent central bank as the most important prerequisite for the conduct of monetary policy seems to be a consensus among academic economists as well as economic policy makers. Recent discussion on this topic are motivated by the practical concern over the establishment of European Central bank, the reforms in the central bank laws in many countries such as New Zealand, Japan, and Korea as well as Transitional Economies, and also the theoretical concern about the problem of dynamic inconsistency in monetary policy.

Theoretically, it is tempting to argue that an independent central banker can control the growth rate of money stock, thereby realize low rate of inflation given other conditions. The most important theoretical work which supports the need of an independent central bank is Rogoff (1985). He shows that a conservative central banker eliminates the inflation bias at the sacrifice of the stability of output using the model of dynamic inconsistency, originated by Kydland and Prescott (1977) and Barro and Gordon (1983). Namely, Rogoff (1985) proved that the delegation of monetary policy to a conservative and independent central banker in a sense that his or her distaste for inflation is stronger than society is one of the useful ways to reduce the inflation bias. Recently, Perrson and Tabellini (1993) and Walsh (1995) show that a liner incentive contract between the government and the instrument independent central banker based on the realized rate of inflation will lead the same economy as Rogoff (1985) analyzed to the first best equilibrium, and that the trade-off between the inflation bias and the stability of output stability is resolved. Svensson (1995) extends the analysis of Walsh (1995) to more general cases. While Posen (1995) argues that the delegation of monetary policy to a conservative central banker is not the sufficient condition to achieve price stability, there seems to be a widespread agreement that establishing an independent central bank is not counterproductive as Fischer (1995) stressed.

In the mean time, there are a lot of empirical studies on the relationship between the degree of central bank independence and the rate of inflation. Bade and Parkin (1985) observe the differences in the rate of inflation among developed countries after the collapse of fixed exchange rate system. They suspect that the increase in the degree of freedom to execute monetary policy under the regime of floating exchange rate bring about the differences in the degree of central bank independence among those countries, which leads to the observed cross-country dispersion of the rate of inflation. To examine their hypothesis, they classify the degree of central bank independence among industrialized countries into several types based on the central bank laws. According to their analysis, the average rate of inflation is significantly lower in countries with highly independent central banks compare with those without.

Following the pioneering study by Bade and Parkin (1985), Alesina (1988), Grillin, Masciandaro and Tabellini (1991), Cukierman, Webb and Neyapti (1992), and Alesina and Summers (1993) are well-known studies to construct other indexes of central bank independence. Cukierman and Webb (1995), Loungani and Sheets (1995) are few examples which expand the analysis into developing countries and transitional economies. Armed with those indexes of central bank independence, most studies on this subject examine the relationship between the average rate of inflation and the index of central bank independence using the regression equation such as equation (1),

$$\pi(s,\tau)_j = c_0 + c_1 \cdot CBI_j + \varepsilon_j \qquad \textbf{(1)}$$

where $\pi(s,\tau)_j$ is the average rate of inflation of country j between time s and τ, CBI_j is the index of central bank independence for country j (higher value of *CBI* means more independent central bank), and ε_j is statistical error term. Eijffinger and de Haan (1996) summarizes that the majority of studies find that c_1 is negative and significantly different from zero.

Our paper expands such conventional analysis in both theoretical and empirical directions.

First, on theoretical ground, the conventional analysis assumes that there is no relevant variable except CBI that might affect the cross country differences in the rate of inflation as seen in equation (1). We argue that it is important to control for the effect of money stock and real income when one compares the rate of inflation of one country with those of others, because the quantity theory of money predicts cross-country differences in the rate of inflation reasonably well, as Lucas (1980), Duck (1993) and Romer (1996) stressed.

Second, on empirical ground, the conventional analysis assumes that time series average rate of inflation in each country is useful indicator of the long run rate of inflation as used in equation (1). We suggest that the country fixed effect estimated from the panel data regression of the rate of inflation on the growth rate of money stock and that of real income will be an useful indicator of the long run country specific rate of inflation which cannot be explained by the quantity theory of money. The country fixed effect obtained in this way can measure the degree of central bank independence because it predicts differences in the rate of inflation even after controlling for the growth of money stock and that of real income. We argue that it is not the time series average rate of inflation, but the estimates of country fixed effect, that should be compared with the index of central bank independence, as Fujiki (1996) proposed. We find that among industrial countries, country fixed effect is negatively correlated with the index of central bank independence by Cukierman, Webb and Neyapti (1992), however the negative correlation becomes unstable once we take into account of the effect of other variables and restricting the periods of estimation to the recent sample periods. The results suggest that we should be cautious about the recent policy suggestion such as "most obviously they suggest the economic performance merits of central bank independence." (Alesina and Summers(1993), p159)

The organization of this paper is as follows. Section 2 discusses our theoretical and empirical framework. Section 3 introduces our data set. Section 4 summarizes our empirical findings. Section 5 concludes.

2. A Monetarist Model

In this section, we discuss our theoretical and empirical model.

Some former studies on the relationship between the index of central bank independence and the rate of inflation are aware of the risk of some omitting variables that might change the implication of equation (1).

For example, as advocated by Romer (1993), Openness ((Export + Import)/GDP) and the level of initial income are relevant variables to explain cross-country difference in the rate of inflation. Hence it is better to estimate equation (2) rather than equation (1) to check the statistical relationship between the rate of inflation and the index of central bank independence.

$$\pi(s,\tau)_j = a_0 + a_1 \cdot OPEN_j + a_2 \cdot INIY_j + a_3 \cdot CBI_j + \varepsilon_j \qquad \textbf{(2)}$$

where $OPEN_j$ is the average degree of openness of country j, and $INIY_j$ is the level of initial income per capita, namely, per capita income of country j at time s . In equation (2), a_3 quantifies the effect of the index of central bank independence on the average rate of inflation conditional upon the degree of openness and the initial level of income per capita.[1]

In this study, we restrict our attentions to the OECD countries as Alesina and Summers (1993) did. If we restrict the analysis within high-income countries, Romer

[1] There are other plausible controlling variables in the right hand side of equation (2). For example, Al-Marhubi and Willett (1995) introduces openness, degree of exchange rate fixedness and budget deficit. Cukierman *et. al* (1993) includes a terms of trade measure.

(1993) finds that the degree of openness is not a crucial control variable to compare the rate of inflation. Instead of the degree of openness, we argue that it is important to take into account of the quantity theory of money, namely,

$$M_{jt}V_{jt} = P_{jt}Y_{jt} \qquad \textbf{(3)}$$

where *M* is money stock, *V* is velocity, *P* is aggregate price level, *Y* is aggregate income, and subscript t shows time and j implies country j. Expressing equation (3) in terms of changes over time, we find simple equation to determine the rate of inflation,

$$\pi_{jt} = GRM_{jt} + GRV_{jt} - GRY_{jt} \qquad \textbf{(4)}$$

where *GRM* is the growth rate of money stock, *GRV* is the growth rate of velocity, and *GRY* is the growth rate of real income.

If *GRV* is constant over time, equation (4) is a simple structural equation that determines the rate of inflation. This is because in the long run, the growth rate of money stock is controlled by the central bank, and the level of real output is determined by the level of employment consistent with the condition of labor market, and both of them are not affected by the rate of inflation (i.e. exogeneity of GRM and GRY). We argue that such variables as *GRM* and *GRY* are important to compare the rate of inflation across countries. Indeed, Duck (1993) finds that the quantity theory of money is useful to explain the differences in the rate of inflation in the long run[2].

Following the quantity theory of money, in order to quantify the effect of the index of central bank independence on the rate of inflation, we can run the regression equation (5);

$$\overline{\pi_j} = a_0 + a_1 \cdot \overline{GRM_j} + a_2 \cdot \overline{GRY_j} + a_3 \cdot CBI_j + a_4 \cdot INIY_j + \varepsilon_j \qquad \textbf{(5)}$$

where upper bar indicates time series average within each country.

This is a variant of regression equation (2), which replaces openness with the average growth rate of money stock (GRM) and that of aggregate income (GRY). Here, we regard *INIY* as the proxy of financial sophistication, or the average level of velocity in each country. It is also possible to regard *INIY* as the proxy of the level of technology to avoid inflation (See Campillo and Miron (1996) about such interpretation).

[2] Duck (1993) assume that growth rate of velocity is a function of the changes in the interest rate.

We can extend regression equation (5) further. An obvious alternative is to run the following equation (6) if we believe that the quantity theory of money holds even in the short run;

$$\pi_{jt} = b_0 + b_1 \cdot GRM_{jt} + b_2 \cdot GRY_{jt} + b_3 \cdot CBI_j + b_4 \cdot INIY_j + \mu_{jt} \qquad \textbf{(6)}$$

where $E[\mu_{jt}{}^2] = \sigma_{jj}$, $\mathrm{cov}[\mu_{jt}, \mu_{kt}] = \sigma_{jk}$, and $\mu_{jt} = \rho_j \mu_{j,t-1} + u_{jt}$.

Observe that *CBI* is close to constant for most countries over time, and to stress this point, *CBI* has only j subscript. One might be interested in the behavior of the error term, μ_{jt} because equation (5) essentially assumes that error terms are not correlated across countries and constant within the country over time, and the error term relationship in (6) holds on average.

Another interesting extension is the fixed-effect model to take care of the country fixed factor which *INIY* cannot explain,

$$\pi_{jt} = c_j + c_t + c_1 \cdot GRM_{jt} + c_2 \cdot GRY_{jt} + c_3 \cdot CBI_j + c_4 \cdot INIY_j + \mu_{jt} \qquad \textbf{(7)}$$

where c_j is country fixed-effect dummy for county j, and c_t is time fixed-effect dummy for year t. As discussed in Fujiki and Kitamura (1995), the fixed effect model is useful to remove the bias in equation (5) due to some omitted variables or unobservables[3]. The fixed effect model seems to become popular among the growth literature (see Islam (1995) for example), but Eijffinger, van Rooiji and Schaling (1996) seems to be the first contribution that uses the technique of panel data regression in the analysis of central bank independence.

However, it is impossible to identify the fixed effects, *CBI*, and *INIY* separately in equation (7). This is because most of the indexes of central bank independence are almost constant for a country over time, and by definition, *INIY* is constant over time. There are several ways to recover c_3 and c_4 separately from c_j, as Baltagi (1995) summarizes[4]. However, the methods discussed in Baltagi (1995) require strong and rather implausible identifying assumptions. Hence we use short-cut two step method here as Fujiki (1996) proposed.

We first estimate the following equation (8)

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[3] Indeed, in case of international comparisons, we argue that it is essential to control exogenous variables so as to isolate the relationship of interest. In other words, we have to set an environment of comparative statics, i.e. other things being equal or *ceteris paribus*.

[4] See pp.116-120 in particular.

$$\pi_{jt} = c_j + c_t + c_1 \cdot GRM_{jt} + c_2 \cdot GRY_{jt} + \mu_{jt} \qquad (8)$$

We argue that the estimates of c_j recovers the long run country specific average rate of inflation of country j net of the effect of growth rate of money stock and that of real income, as well as the simultaneous shock common to the world. Given the same growth rate of money stock and that of real income, the rate of inflation can differ due to the differences in the credibility of central banker, or the degree of central bank independence broadly speaking. Of course, one can argue that the growth rate of money stock (money supply) and the index of central bank independence are closely related and therefore that these two variables are not separable. However, we would like to make a clear distinction between the growth rate of money stock (money supply) as an operational variable of the central bank and the index of the central bank independence as a legal framework of the central bank. It implies that these two variables are qualitatively different, meaning that the former is time dependent and the latter is constant[5]. It seems fairly sensible to highlight the central bank independence after controlling the growth rate of money stock. Therefore, we regress the estimates of c_j on the index of central bank independence and other variables which might be correlated with other long run factors than the degree of central bank independence, such as initial income per capita, as equation (9):

$$c_j = d_1 + d_2 \cdot CBI_j + d_3 \cdot INIY_j + \omega_j \qquad (9)$$

Note that to obtain consistent estimates of d_2 in equation (9), we must estimate c_j in equation (8) consistently. The quantity theory of money suggests that *GRM* and *GRY* are exogenous to the rate of inflation. Moreover, it is known that within estimator obtained by OLS is asymptotically equivalent to the more sophisticated GLS estimator (see Baglati (1995), p.34). Hence for the sake of initial estimation of equation (8), it suffices to use simple OLS estimation.[6]

The relationship between the equation (5) and two step approach of equation (8) and (9) is as follows. Estimating equation (5) is equivalent to run equation (8) without any control variables other than country fixed effect and run equation (9)

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[5] In a somewhat related context, Cukierman (1992: p.369) argues that legal independence of central bank is not the same sa acutal independence and that leral independence only measures one aspect of acutal central bank independence.

[6] We thank Prof. Kuroki (Osaka Prefectural University) for his suggestion on this issue.

without *INIY*. Equation (8) differs from equation (5) since it considers simultaneous shock to the world rate of inflation by the introduction of time effect (e.g. the oil price shock), and regards the average rate of inflation of each country after taking out of common time effect and the growth rate of money stock and that of real income as the country specific average rate of inflation, not the simple time series average rate of inflation.

We believe that our two step approach has advantage over the conventional approach because the regression equation (5) cannot clearly separate long run fixed factors from the degree of central bank independence, while our approach can identify the nature of long run factors in the rate of inflation more explicitly.

3. Data

This section explains the data used in the following empirical examination.

We picked up the proxy of *Y*, *M* and *P* from IFS database (IMF). In particular, we select real GDP for the proxy of *Y*, M1+Quasi-Money as a proxy for *M*, GDP deflator for the proxy of *P*. GDP deflator is relevant here since it measures the home made rate of inflation, which seems to be under the control of central banks. There could be other way to measure the level of transaction other than GDP, however for the sake of international comparison, GDP seems to be the most reliable data.

Note that in case of Italy, quasi-money is available only after 1975, hence we used M1. We used annual data from 1961 to 1990. However, the data of *Y* before 1959 is not available for Germany. *P* is available only up to 1977 for Germany, hence we used OECD MEI dataset to fill the data for these periods. Finally, we use the legal index of central bank independence by Cukierman, Webb and Neyapti (1992) for *CBI*[7].

4. Results of Regressions

This section reports the results of estimation and discusses the implications of our empirical findings.

First, in order to compare our model with former studies, we estimate equation (5) by OLS, and compute the standard errors by the methods suggested by White (1980). Table 1 shows the results of estimation using the sample period of 1961-90. The first column shows the explanatory variables, second column reports the results of

[7] Currently many economists in this field use the Penn World Table, however, it does not contain the data on money supply. So we do not use it here.

estimation without using *INIY* as a regressor, and the third column contains the results of estimation using all of the independent variables listed in the first column.

The coefficient of the average growth rate of income, *GRY*, is negative and significantly lower than zero, and the coefficient of the average growth rate of money stock, *GRM*, is positive and significantly different from zero. With and without conditioning *INIY*, *CBI* is negative and statistically significantly different from zero. Those results are consistent with the quantity theory of money, and the empirical findings of negative correlation between the average rate of inflation and the degree of central bank independence. Note that our results are not consistent with the finding of Martin (1994) who argues country size, which is closely related to *INIY*, predicts the rate of inflation. Our result, on the contrary, shows that *INIY* is statistically insignificant to explain cross-country variation of average rate of inflation once holding the degree of central bank independence constant.

Table 2 and Table 3 report the results of estimation of equation (5) using sample periods of 1975-90 and 1981-90 respectively. The results suggest that *GRY* becomes insignificant to predict the average rate of inflation, while *GRM* is still highly significant. Observe that once we introduce *INIY* as an additional explanatory variable, the absolute value of the coefficient of *CBI* decreases, the standard errors of *CBI* increases, and *CBI* cannot be the strong factor to predict the average rate of inflation[8]. The results here are consistent with the current study by Campillo and Miron (1996), which stress the importance of the structural factors other than the degree of central bank independence to explain the average rate of inflation.

Next, we report the results of estimation of equation (6). We propose three specifications of groupwise heteroscedasticy and three specification of autocorrelation in the error term, hence we have nine models to examine (for statistical details, see, for example, Greene (1993,1995)). More precisely, for groupwise heteroskedasticity, let $\Sigma = \left[\sigma_{jk}\right]$ (j=1,..16, k=1,...,16) be 16×16 period specific covariance matrix. The following three assumptions can be made:

S0: $\Sigma = \sigma \mathbf{I}$ (homoskedastic regression) ,
S1: $\Sigma = Diag\left[\sigma_{1,1}, \cdots, \sigma_{16,16}\right]$ (groupwise heteroskedastic),
S2: Σ is 16×16 positive definite matrix, groupwise heteroskedastic and cross group correlated.

[8] Note, however, that in the presence of two country specific fixed effects of *CBI* and *INIY*, *CBI* remains important as *INIY* is statistically less significant than *CBI* throughout Tables 1-3.

For the specification of serial correlation, we suppose:

R0: $\rho_j = 0$ for all j (no autocorrelation) ,
R1: $\rho_j = \rho$ for all j (common autocorrelation),
R2: $\rho_j \neq \rho_k$ for different j and k (group specific autocorrelation).

We run nine regressions using sample period from 1961 to 1990 to examine all of the combination of groupwise heteoskedasticity and autocorrelation proposed above by the TSCS procedures in the statistical package LIMDEP 7.0 (Greene (1995)). The major findings from those nine regressions are: (1) that the growth rate of money stock, *GRM*, and that of real income, *GRY*, are important factor to explain the rate of inflation, (2) that for eight out of nine models, the estimated coefficients on *CBI* are negative and statistically significantly different from zero, (3) that *INIY* is not statistically significant.

For the sake of selecting relevant specification out of nine models estimated above, we can use the likelihood ratio test to examine the restrictions on the behavior of error term comparing each model with the most general model under assumptions of R2 and S2. Table 4 summarizes the log-likelihood of each model.[9]

To compare the model with R1 and that with R2 given the same assumptions on heteroskedasticity, the critical value of chi-squared distribution at 5% level with degree of freedom 15 is 25, hence we need the gap of log-likelihood between the model with R1 and that with R2 more than 12.5 to reject the restricted model. In fact, for all S0, S1, and S2, we cannot reject the assumption that autocorrelation coefficents are the same across cross-sectional unit in each case. To compare the model with R0 and that with R1, 5 % critical value of chi-squared distribution of degree of freedom 1 is 3.84. Hence for S0, S1, and S2, we reject the assumption that there is no serial correlation. Similarly, we can test the model with S1 against that with S2 using the chi-squared distribution of degree of freedom 120, given the same specification of autocorrelation. The critical value for 5% seems to be more than 120, however the difference of log-likelihood between the model with S1 and that with S2, given the same specification of autocorrelation is large enough to reject the restriction of S1, groupwise heteroskedasticity.

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[9] For the sake of testing assumptions on error term and serial correlation, suppose one compares a general model whose log-likelihood is L1 with m1 estimated parameters and a restricted model whose log-likelihood is L2 with m2 estimated parameters (m2<m1). If the null hypothesis that a restricted model is true, then 2(L1-L2)/(m1-m2) follows the chi-squared distribution with degree of freedom (m1-m2).

In sum, the model with R1 and S2, and the model with R2 and S2 seem to be relevant specification of error terms for equation (6), hence we report the results of estimation of those two models in Table 5. The model with R2 and S2 shows the results consistent with those reported in Table 1, however, the model with R1 and S2 shows that *CBI* is not a significant explanatory variable for the rate of inflation. Note that this result should not be exaggerated since this specification is the only one out of nine models estimated here that rejects the significance of *CBI*. Nevertheless this result implies that we cannot take the negative correlation between the degree of central bank independence and rate of inflation for granted.[10]

Now we discuss the results of regression of equation (8). Table 6 reports the results of estimation using the sample periods of 1961-1990, 1975-1990 and 1981-1990. It is clear that the quantity theory of money is useful to predict the rate of inflation in the long run as can be seen the results using the sample period of 1961-1990 in which country fixed effects are statistically significant for most cases. Observe that time effect captures the two world wide inflation periods from 1973 to 1975, and from 1979 to 1981. We suspect that those world wide oil price shocks are the sources of common correlation in the estimation of model of equation (6). Campillo and Miron (1996) argue that it is important to control for the effect of the changes in the international currency system occurred in the early 1970s, and propose to add some dummy variable to control such shocks. Our time effect will also take care of the effect of such once-for-all shocks due to the introduction of the floating foreign exchange rate system.

We are now ready to examine the relationship between the estimated country fixed effect, c_j, and the degree of central bank independence, *CBI*. Let us look at Figure 1, which plots the estimated country fixed effect using the sample period of 1961-90 versus the index of central bank independence. It nicely predicts a negative relationship between the degree of central bank independence and the estimated country fixed effect. To confirm this observation, Table 7 reports the results of regression of equation (9) and indeed finds negative correlation between the index of central bank independence and the estimated country fixed effect with and without *INIY*. Table 8 and Table 9 summarize the results of estimation of equation (9) with the shorter sample periods of estimation of equation (8).

To put it differently, judging from Tables 7-9, *INIY* is insignificant and the regression models without *INIY* are statistically superior to those with *INIY*. We can

[10] As the model with R2 and S2 estimates 157 parameters in total, hence it is impossible to estimate equation (6) using the shorter sample periods of data. We only report the results using the sample period of 1961-90.

drop *INIY* from equation (9). Then equation (9) expresses a simple linear relationship between the country fixed effect and the index of central bank independence. Figure 1 indicates that the index of central bank independence and the estimated country fixed effect are correlated (correlation coefficient without *INIY* = -0.54 with t-value 2.145, significant at 5% level). This correlation is significant but not as high as we expected. There are at least two reasons. First, Eijffinger, van Rooji and Schaling (1996) interpret the estimated country fixed effect as actual index of central bank independence and argue that legal index of central bank independence (i.e. *CBI*) is not the same as actual index of central bank independence. If we accept their interpretation, our estimated country fixed effect as actual index of central bank independence may be closely related to *CBI* but may not show one-to-one correspondence. It may reflect, on the one hand, that *CBI* is constructed on arbitrary choices of criteria and, on the other hand, that the country fixed effect captures all country-specific features including the central bank independence[11]. Secondly, bearing these facts in mind, Figure 1 shows that Belgium, Japan, and Norway seem to be outliers of the relationship between the fixed effect and *CBI*. These three countries may have common biases in construction of legal index of central bank independence[12]. We leave this investigation for a future research.

Furthermore, Table 6 shows that the country fixed effect changes over time. For example, that of Japan changes from 2.7773 in 1961-90, to 0.8427 in 1975-90 and to 0.7769 in 1981-90. In particular, that in 1981-90 is the lowest in the sample. It does not imply that the degree of central bank independence in Japan rose suddenly in that period. It may be a result of domestic and international macroeconomic environments, including a high yen appreciation. In this sense, we have to be careful in interpreting the country fixed effect as actual index of central bank independence. It is worthwhile noting that the quantity theory of money does not seem to work in 1975-90 as the coefficient of GRM becomes insignificant during the same period.

In sum, our empirical results amply show that there exist country-specific differences even after controlling the growth rate of money stock and that of aggregate income. In other words, there are something that the quantity theory of money cannot explain. Whether or not we call this country-specific fixed effect as actual index of central bank independence, we find the county fixed effect very important and useful to identify heterogeneity of countries.

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[11] For example, Mauro (1995) argues that the degree of corruption makes different economic performance among countries.

[12] These three countries seem actually more independent than legal indices show.

Lastly, we would like to compare the results with those in Fujiki (1996). In fact, Fujiki (1996) based on the model presented in Appendix I of Romer (1993) where openness of the country plays a crucial role. Openness variable is rather insignificant when the sample is restricted to the industrialized countries. While the quantity theory of money is valid even for the industrialized countries, although it becomes less significant in recent years. It is fair to say that in order to explain the rate of inflation in the long run, the quantity theory of money seems to work better than the Romer model of openness.

5. Summary and Conclusion

We argue that one of the most important theories to predict the long run rate of inflation is the quantity theory of money. However, most empirical studies of central bank independence do not take into account of the quantity theory of money explicitly. In this paper, we find that the quantity theory of money is useful to predict the long run rate of inflation, and after controlling the rate of inflation by the quantity theory of money, we obtain the country fixed effect which turns out to be negatively correlated with the index of central bank independence.

We are still not convinced to claim this country fixed effect as actual index of central bank independence as Eijffinger, van Rooji and Schaling (1996) do. Nevertheless we are quite confident that there is heterogeneity among countries that the quantity theory of money cannot explain and the fixed effect model of panel data approach is a quite powerful way to identify this heterogeneity.

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Table 1. Results of Regression Equation (5):

The Period 1961-1990

Dependent Variable = Average rate of inflation from 1961-90						
	Estimate	S.E.	t-value	Estimate	S.E.	t-value
Constant	4.3700	1.7110	2.5540	5.4763	12.6174	0.4340
$\overline{GRY}_j$	-0.9258	0.3165	-2.9252	-0.9485	0.3714	-2.5540
$\overline{GRM}_j$	0.5932	0.1018	5.8271	0.5899	0.1111	5.3110
CBI_j	-3.8337	1.3761	-2.7858	-3.7859	1.4762	-2.5646
$INIY_j$				-0.1142	1.2977	-0.0880
R^2	0.782			0.762		
S.E.	0.952			0.994		
Sample	1961-90			1961-90		

Note: Standard Error of estimates are computed following White(1980).

Table 2. Results of Regression Equation (5):

The Period 1975-1990

Dependent Variable = Average rate of inflation from 1975-90						
	Estimate	S.E.	t-value	Estimate	S.E.	t-value
Constant	4.7806	2.7542	1.7358	19.1452	30.7080	0.6235
$\overline{GRY}_j$	-0.7495	0.7189	-1.0425	-0.8054	0.7108	-1.1331
$\overline{GRM}_j$	0.5348	0.1249	4.2834	0.5282	0.1235	4.2776
CBI_j	-5.4962	2.4662	-2.2286	-4.6374	2.5239	-1.8374
$INIY_j$				-1.5626	3.3765	-0.4628
$\overline{R}^2$	0.626			0.597		
S.E.	1.991			2.066		
Sample	1975-90			1975-90		

Note: Standard Error of estimates are computed following White(1980).

Table 3. Results of Regression Equation (5):

The Period 1981-1990

Dependent Variable = Average rate of inflation from 1981-90						
	Estimate	S.E.	t-value	Estimate	S.E.	t-value
Constant	9.0190	3.4782	2.5930	25.2326	33.0985	0.7623
$\overline{GRY}_j$	-1.4427	1.0313	-1.3989	-1.4561	1.0392	-1.4012
$\overline{GRM}_j$	0.2252	0.0917	2.4542	0.2154	0.0980	2.1985
CBI_j	-5.5659	2.6058	-2.1360	-4.7037	2.7066	-1.7379
$INIY_j$				-1.7507	3.5077	-0.4991
$\overline{R}^2$	0.303			0.253		
S.E.	2.225			2.303		
Sample	1981-90			1981-90		

Note: Standard Error of estimates are computed following White(1980).

Table 4. Log-likelihood Functions for Estimated Models

	R0		R1		R2	
	Log-L	Parameters	Log-L	Parameters	Log-L	Parameters
S0	-1319.99	6	-1146.16	7	-1143.10	22
S1	-1264.65	21	-1082.68	22	-1079.99	37
S2	-993.44	141	-936.35	142	-929.62	157

Notes: The following specification for the error term are considerd.

For groupwise heteroskedasiticity, let $\Sigma = [\sigma_{jk}]$ (j=1,..16, k=1,...,16) be 16 × 16 period specific covariance matrix. The following three assumptions can be made:

S0: $\Sigma = \sigma \mathbf{I}$ (homoskedastic regression)

S1: $\Sigma = Diag[\sigma_{1,1}, \cdots, \sigma_{16,16}]$ (groupwise heteroskedastic)

S2: Σ is 16×16 positive definite matrix, groupwise heteroskedastic and cross group correlated.

For the specification of serial correlation,

R0: $\rho_j = 0$ for all j (no autocorrelation)

R1: $\rho_j = \rho$ for all j (common autocorrelation)

R2: $\rho_j \neq \rho_k$ for different j and k (group specific serial autocorrelation)

Table 5. Results of Regression Equation (6)

Dependent Variable = Rate of inflation						
	Estimate	S.E.	t-value	Estimate	S.E.	t-value
Constant	4.9490	0.8926	5.5450	5.2486	0.7819	6.7120
GRY_{jt}	-0.1283	0.0313	-4.0960	-0.1142	0.0290	-3.9410
GRM_{jt}	0.0289	0.0069	4.2020	0.0360	0.0068	5.2950
CBI_j	-0.9342	0.9885	-0.9450	-3.2783	0.8782	-3.7330
$INIY_j$	-0.0001	0.0001	-0.8590	4.16E-06	0.0001	0.0440
LLR	-936.353			-929.615		
Model	S2, R1			S2,R2		
Estimation	Iterated MLE GLS method			Iterated MLE GLS method		
Sample	1961-90			1961-90		

Note: Model S2, R1 predicts estimated common autocorrelation coefficient to be 0.65374
Model S2, R2 predicts the following group specific autocorrelation

0.627	0.636	0.699	0.85	0.682	0.536	0.575	0.685
0.678	0.604	0.779	0.551	0.638	0.605	0.833	0.482

Model S2, R1 is the following model:

$$\pi_{jt} = b_0 + b_1 \cdot GRM_{jt} + b_2 \cdot GRY_{jt} + b_3 \cdot CBI_j + b_4 \cdot INIY_j + \mu_{jt}$$

where $E[\mu_{jt}^2] = \sigma_{jj}$, $\text{cov}[\mu_{jt}, \mu_{kt}] = \sigma_{jk}$, $\mu_{jt} = \rho_j \mu_{j,t-1} + u_{jt}$, and $\Sigma = [\sigma_{jk}]$ (j=1,..16, k=1,...,16) be 16×16 period specific covariance matrix, with the assumption that S2: Σ is 16×16 positive definite matrix, groupwise heteroskedastic and cross group correlated, and R1: $\rho_j = \rho$ for all j (common autocorrelation)

Model S2, R2 is the following model:

$$\pi_{jt} = b_0 + b_1 \cdot GRM_{jt} + b_2 \cdot GRY_{jt} + b_3 \cdot CBI_j + b_4 \cdot INIY_j + \mu_{jt}$$

where $E[\mu_{jt}^2] = \sigma_{jj}$, $\text{cov}[\mu_{jt}, \mu_{kt}] = \sigma_{jk}$, $\mu_{jt} = \rho_j \mu_{j,t-1} + u_{jt}$, and $\Sigma = [\sigma_{jk}]$ (j=1,..16, k=1,...,16) be 16×16 period specific covariance matrix, with the assumption that S2: Σ is 16*16 positive definite matrix, groupwise heteroskedastic and cross group correlated, and R2: $\rho_j \neq \rho_k$ for different j and k (group specific serial autocorrelation)

Table 6. Results of Regression Equation (8)

Dependent Variable = Rate of Inflation									
	Estimate	S.E.	t-value	Estimate	S.E.	t-value	Estimate	S.E.	t-value
CANADA	3.0301	0.6693	4.5270	3.7948	0.7385	5.1384	3.8724	0.6533	5.9271
U.S.A.	2.5632	0.6511	3.9367	3.3396	0.7173	4.6554	3.5103	0.6245	5.6209
JAPAN	2.7773	0.9340	2.9735	0.8427	0.8069	1.0443	0.7769	0.7709	1.0078
BELGIUM	2.5116	0.6786	3.7013	2.4210	0.8091	2.9923	3.1524	0.6935	4.5457
DENMARK	4.6625	0.6598	7.0664	4.3541	0.6886	6.3227	4.4337	0.5907	7.5056
FRANCE	4.2018	0.6499	6.4654	5.2731	0.7317	7.2071	5.1189	0.7323	6.9901
GERMANY	1.4346	0.7016	2.0449	0.7325	0.8077	0.9069	1.6093	0.6961	2.3121
ITALY	7.4670	0.8813	8.4731	10.3616	0.9618	10.7728	9.3074	0.9640	9.6555
NETHERLANDS	2.5635	0.7548	3.3964	1.2187	0.7309	1.6676	1.0009	0.7011	1.4277
NORWAY	3.9909	0.6997	5.7038	4.6944	0.8856	5.3009	4.9720	0.8805	5.6470
SPAIN	8.0213	0.8699	9.2208	9.8863	1.0189	9.7028	8.2782	0.7180	11.5288
SWITZERLAND	4.6714	0.7271	6.4249	6.2046	0.7511	8.2609	6.4382	0.7444	8.6489
SWEDEN	2.0373	0.8408	2.4231	0.8362	1.0673	0.7834	2.8980	0.7544	3.8415
U.K.	5.1938	0.8488	6.1191	7.3713	1.2688	5.8097	4.7660	0.7206	6.6137
AUSTRALIA	4.6600	0.7041	6.6181	6.3101	0.7663	8.2341	6.4052	0.6820	9.3913
NEWZEALAND	5.8774	0.9962	5.8998	8.5911	1.1923	7.2053	8.4081	1.3942	6.0306
T61	-0.9567	0.9434	-1.0141						
T62	0.0209	0.8140	0.0257						
T63	0.1972	0.8102	0.2434						
T64	1.5572	1.0312	1.5101						
T65	0.6551	0.8183	0.8005						
T66	0.5081	0.8937	0.5685						
T67	-0.1279	0.7804	-0.1639						
T68	-0.0982	0.8555	-0.1147						
T69	1.0342	0.8768	1.1794						
T70	3.7282	0.9325	3.9982						
T71	3.0097	0.9057	3.3230						
T72	2.6266	0.9353	2.8081						
T73	4.8938	0.9027	5.4214						
T74	7.9743	1.1313	7.0490						
T75	7.5567	1.2630	5.9833	7.6381	1.1559	6.6080			
T76	6.2603	1.0773	5.8109	6.4036	0.9910	6.4616			
T77	4.7226	1.1113	4.2497	4.7507	1.0706	4.4372			
T78	3.9037	0.9692	4.0276	4.2441	0.9324	4.5519			
T79	4.2596	0.9526	4.4715	4.3676	0.8468	5.1578			
T80	5.9411	1.1482	5.1743	5.8313	1.0081	5.7845			
T81	5.2039	0.9783	5.3195	5.1989	0.9041	5.7503	5.2103	0.8716	5.9778
T82	4.1404	0.8742	4.7361	4.0505	0.8759	4.6242	4.0757	0.8231	4.9515
T83	2.1485	0.8373	2.5661	2.0060	0.8162	2.4576	2.0162	0.7207	2.7975
T84	1.4994	0.7244	2.0698	1.4894	0.7774	1.9159	1.4725	0.6387	2.3053
T85	1.2054	0.8062	1.4951	1.2021	0.8636	1.3920	1.1925	0.7342	1.6242
T86	0.5654	0.9654	0.5857	0.5787	0.9943	0.5820	0.5700	0.8722	0.6535
T87	-0.2388	0.9430	-0.2533	-0.0815	0.9199	-0.0887	-0.1033	0.7893	-0.1308
T88	0.0614	0.7019	0.0874	-0.1028	0.7977	-0.1288	-0.1033	0.6340	-0.1630
T89	0.5256	0.7604	0.6912	0.6250	0.8712	0.7174	0.6087	0.7229	0.8420
GRY	-0.1682	0.0857	-1.9617	-0.2014	0.1104	-1.8235	-0.1879	0.1170	-1.6065
GRM	0.0671	0.0260	2.5764	0.0163	0.0264	0.6179	0.0207	0.0301	0.6877
$\bar{R}^2$	0.583			0.712			0.688		
S.E.	2.77			2.553			2.091		
Sample	1961-90			1975-90			1981-90		

Note: Standard Error of estimates are computed following White(1980).

Figure 1. Estimated fixed effect versus CBI index

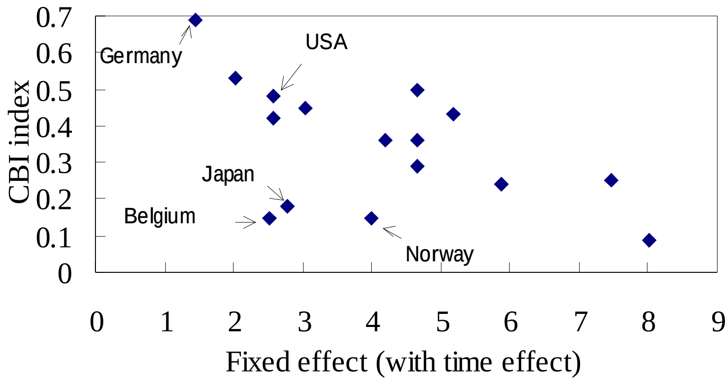

Table 7. Results of Regression Equation (9):

The period 1961-1990

Dependent Variable = Esimated fixed effect (With time effect)						
	Estimate	S.E.	t-value	Estimate	S.E.	t-value
Constant	8.9236	15.6620	0.5698	6.2509	1.1847	5.2765
CBI_j	-5.7839	2.6520	-2.1810	-6.1671	2.5967	-2.3750
$INIY_j$	-0.3200	1.8102	-0.1768			
$\bar{R}^2$	0.1850			0.2410		
S.E.	1.7060			1.6460		
Sample	1961-90			1961-90		

Note: Standard Error of estimates are computed following White(1980).

Table 8. Results of Regression Equation (9):

The Period 1975-1990

Dependent Variable = Esimated fixed effect (With time effect)						
	Estimate	S.E.	t-value	Estimate	S.E.	t-value
Constant	26.8991	39.8914	0.6743	8.2470	1.7243	4.7828
CBI_j	-9.1442	3.3406	-2.7373	-10.4539	3.6144	-2.8923
$INIY_j$	-2.0666	4.3219	-0.4782			
$\bar{R}^2$	0.1900			0.2390		
S.E.	2.8660			2.7760		
Sample	1975-90			1975-90		

Note: Standard Error of estimates are computed following White(1980).

Table 9. Results of Regression Equation (9):

The Period 1981-1990

Dependent Variable = Esimated fixed effect (With time effect)						
	Estimate	S.E.	t-value	Estimate	S.E.	t-value
Constant	32.9676	22.1826	1.4862	6.9586	1.5203	4.5771
CBI_j	-4.9463	3.2517	-1.5212	-6.5214	3.0201	-2.1593
$INIY_j$	-2.8398	2.3902	-1.1881			
$\bar{R}^2$	0.0780			0.1130		
S.E.	2.4850			2.4370		
Sample	1981-90			1981-90		

Note: Standard Error of estimates are computed following White(1980).