Constant Gain in Crisis: A Small Open Economy Case for South Korea

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November 22, 2006

Abstract

This paper proposes that constant gain learning parameter varies across time and particularly in the presence of an economic shock. A New Keynesian open economy recursive forecasting model with one-step ahead VAR forecast is used to examine the case of South Korea around the time of Asian financial crisis in 1997. It is found that the best fitting constant gain least squares increases to its peak at the time of the economic shock and decreases sharply thereafter, suggesting a change in private agents' expectations and forecast formation due to structural change of the economy.

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†I would like to thank Bill Branch for his unrelenting support and encouragement throughout the process of this paper as an understanding advisor.

1 Introduction

Conventional usage of rational expectations has been shown to be increasingly unreliable and unrealistic in modern macroeconomic analysis. In a world where underparameterizaton and misspecification by bounded rational agents are probable[1], rational expectations makes a strong assumption that agents have a full set of information on the structure of the economy whose perfect foresight then renders their expectations coincide with the actual outcome. Not only would such complete knowledge be unlikely in reality, in a dynamic and stochastic economy with unexpected economic shocks, even assigning a probability to an unforeseen and indescribable event itself becomes a challenge. It is now common knowledge that rational expectations in fact fails to account for structural changes of the economy and results in parameter instability. A more plausible assumption sets agents with imperfect knowledge to base their forecast of the next period on the incomplete information of this period and update their learning rule through their mistakes as more data becomes available.[2] How agents use the given information, that is, how much importance they put on data of distant or near past, is captured in the learning gain parameter. In a country with unpredicted shocks, understanding of this gain is even more crucial than in a stable environment as it allows the policy makers to perceive how the path of the economy is influenced by private expectations and how the optimal monetary policy should be formed and implemented.

A fitting example of such a case is East Asia and its financial crisis in the late 1990s. I take the experience of South Korea from 19971 to 2005 to study the response of constant gain learning in the presence of an unanticipated structural change. Constant gain least squares, which puts increasing weight on current data, is shown to be more effective in an environment that exhibits structural breaks relative to other learning rules such as decreasing least squares or time-varying parameters through the Kalman filter.[3] The framework of the paper takes a New Keynesian open economy recursive forecasting model to study real time forecasting in determining the rate at which the data should be discounted when the country is hit by a shock such as in a currency crisis. It is found that the best fitting constant gain actually varies across time. In particular, it peaks at the crisis and drops shortly after as people change their outlook on market stability. Such a finding enhances the understanding of economic behavior and serves as a guide to how the economy should be directed.

2 Rational Expectations and Adaptive Learning

It is widely known knowledge that with the breakdown of Phillips curve and decreasing reliability of Taylor rule on producing desired outcomes, the importance of expectations has

[1]Branch (2004).

[2]Gaspar, Smets, and Vestin (2005).

[3]Branch and Evans (2006) and Molnar and Santoro (2005). Molnar and Santoro also points out that if private agents perceive the economy to be stationary, decreasing gain learning would be more appropriate.

become more recognized. Especially in a dynamic, stochastic economy that is seen to be constantly evolving with series of disturbances, it becomes a forced assumption to think that agents would have all the information needed to know to bring the economy to equilibrium, that is, the rational expectations equilibrium (REE).[4] New Keynesian open economy model shows that assumption of rational expectations when agents are in fact learning would result in parameter instability of the Philips curve.[5]

An alternative portrayal of the economy, and persuasively more realistic, is the notion of bounded rationality. In it, private agents are seen to be limited in their understanding of the environment to only what may have been exposed to them. Consequently, their collection of information is incomplete and uncertain in nature. Agents would form their learning rules according their perceived law of motion (PLM) that delineates what rational expectations equilibrium they believe the economy to be in and update their forecast as more information becomes available. Adaptive learning depicts agents that behave as econometricians as they try to recursively estimate the parameters of the economic structure.

Constant gain least squares in particular allows for persistent learning of the economy by maintaining a constant gain learning parameter of positive value. Although a decreasing gain may lead to an asymptotic convergence to rational expectations equilibrium by tapering its gain sequence to zero over time [6], such gain parameter is only appropriate when the economy is believed to be stationary. For a changing and misspecified economic structure with fluctuations, a single optimal forecast rule with fixed parameters will prove to be ill-fitting. Constant gain least squares instead aims to follow the evolving path of the structural parameters by responding to the latest data with more attention while discounting the past and revises the rule appropriately with each new information. The use of constant gain learning in the presence of notable structural breaks, such as it was seen in the Asian financial crisis, has already begun to be used by a growing number of literature.

3 Literature Review and Contribution

Adaptive learning is still a burgeoning area of research. Furthermore, majority of the literature has been for the most part theoretical or if empirical, with emphasis in big economies such as the U.S and in a closed economy setting. The present paper takes a step into the yet to be explored area of a small open economy case for South Korea. If properly addressed and analyzed, understanding the effects of an economic shock with international implications in Korea can open the doors to designing optimal monetary policy rules that could be

[4] Evans and Honkapohja (2001) define REE as a unique equilibrium of expectations that is mathematically conditioned on relevant variables of the full information available to decision makers.

[5] Molnar and Santoro (2005)

[6] It is, in fact, one of the major weaknesses of a constant gain learning that there is no assurance of convergence to REE.

implemented in other small open economies with modifications for their differences.

A number of literature has already paved the way to show the preference of learning over rational expectations assumption in monetary policy formation, including Evans and Honkapohja (2003)[7], Evans and Honkapohja (2003)[8] and Berardi (2004). These papers explain that an otherwise well-performing and stable monetary policy based on rational expectations could lead to indeterminacy and E-instability when private agents are actually learning. In fact, Bullard and Mitra (2002), Orphanides and Williams (2006)[9], Orphanides and Williams (2006)[10], and Preston (2004) argue that not only should learning be solely from the private sector, but central banks should do their best to learn of private agents' behavior and natural rates of the economy as the private sector tries to estimate the economic structural parameters in order to have effective and stable monetary conditions.

Comparisons of different adaptive forecasting learning rules were offered in Branch and Evans (2006), Lettau and VanZandt (2003), and Stock and Wastson (1996). It was concluded that constant gain learning would be recommended to be the optimal approach to representing the forecasting rule as is employed in Cho and Kasa (2002), Milani (2005)[11], and Milani(2005)[12] and be followed by persistent learning and updating in the coexistence of imperfect knowledge about the economic structure as described in Orphanides and Williams (2005)[13] and Orphanides and Williams (2005)[14] The continuation of learning is especially desirable when there exist model uncertainty and misspecification as noted by Branch and Evans (2005).

Constant gain learning with bounded rationality is, of course, not without flaws of its own. One of the prominent concerns is its lack of assurance in converging to the rational expectations equilibrium. Work by Preston (2005), Preston (2006), and Honkapohja and Mitra (2003) are of noteworthy accusations of such weakness. However, as it is beyond the scope of the present paper to examine in depth the advantages and disadvantages of different learning rules than already discussed here, I take as a given that constant gain least squares

[7] Evans, G. and Honkapohja, S., 2003, "Adaptive Learning and Monetary Policy Design", Journal of Money, Credit and Banking 35, 1045-1072.

[8] Evans, G. and Honkapohja, S., 2003, "Expectations and the Stability Problem for Optimal Monetary Policy", Review of Economic Studies 70, 807-824.

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be the ideal choice of learning algorithm for a country with unexpected economic shocks and apply it in my model. Lastly, it is also helpful to point out that economies with economic shocks or irregularities were addressed in Batini and Haldane (1999), Marcet and Nicolini (2003), and Kasa (2004), that promoted forecast-based rules under bounded rationality to account for the structural changes.

4 The Model

The main objective of this paper is to observe and explain the changes in the best fitting constant gain found by least squares in response to an economic shock. The framework is that of a New Keynesian open economy recursive forcasting model with one-stop ahead vector autoregression (VAR) forecast. The hypothesis expects the learning parameter to vary across time. In particular, it will increase during the financial crisis as agents put more emphasis on the latest information of recent irregularity and return to a lower level as the economy settles back to a more stable condition and the weight is redistributed more evenly across the available data.

4.1 Sample Periods

The New Keynesian open economy recursive forecasting model adopts the notation of Branch and Evans (2006), Evans and Honkapohja (2001), and Milani (2005). The sample is divided into three time intervals around the 1997 Asian financial crisis, consisting of pre-sample, in-sample, and out-of-sample periods. The pre-sample is primarily used to form prior beliefs. Though a specific length of the period may not be crucial, a long enough one is necessary to prevent "over-sensitivity of the initial in-sample estimates."[15] I choose a fifteen-year period from 1971:1 to 1984:4 to run the vector autoregression. The in-sample period starts from the end of the pre-sample period to different cutoff points around the time of crisis. Taking varying places to end the in-sample period, before, during, and after the shock, lets me study the effect of a sudden structural break on the value of the optimal learning gain. The out-of-sample period is then the remaining of the data, from the end of in-sample period to the current year, and explains the difference in forecast performance of gains obtained in various in-sample periods.

4.2 Data

Three economic indicators in percentage changes are employed in the analysis: real GDP growth, inflation, and change in terms of trade. Real output growth is seasonally adjusted

[15] Branch and Evans (2006).

and expressed as log(realgdpsa/realgdpsa(-1)). GDP deflator, which is the ratio of nominal GDP to real GDP, is inflation in the model and calculated as log(gdpdefl/gdpdefl(-1)). Lastly, change in terms of trade is defined as change in price of foreign goods in terms of home goods[16] and carries similar implication as nominal effective exchange rate of a country. Terms of trade is included to reflect the increasing importance of foreign influence in an open economy. Terms of trade change, too, is in terms of log(tot/tot(-1)). All data are measured in quarterly terms and obtained from Global Insight[17], Bank of Korea[18], and National Statistical Office of Korea[19].

4.3 Open Economy Recursive Forecasting Model

4.3.1 Pre-Sample Period

The AR(1) expressions for real output growth, inflation, and change in terms of trade are as follows, respectively:

$$\begin{aligned} gdp_t &= a_{1,t} + b_{1,t} gdp_{t-1} + b_{2,t} inf_{t-1} + b_{3,t} tot_{t-1} + \varepsilon_{1,t} \\ inf_t &= a_{2,t} + c_{1,t} gdp_{t-1} + c_{2,t} inf_{t-1} + c_{3,t} tot_{t-1} + \varepsilon_{2,t} \\ tot_t &= a_{3,t} + d_{1,t} gdp_{t-1} + d_{2,t} inf_{t-1} + d_{3,t} tot_{t-1} + \varepsilon_{3,t} \end{aligned} \tag{1}$$

where y is set to be a column vector of data for the three variables so that

$$y_{j,t} = \begin{pmatrix} y_{1,t} \\ y_{2,t} \\ y_{3,t} \end{pmatrix} = \begin{pmatrix} gdp_t \\ inf_t \\ tot_t \end{pmatrix} = \begin{pmatrix} a_{1,t} \\ a_{2,t} \\ a_{3,t} \end{pmatrix} + \begin{pmatrix} b_{1,t} & b_{2,t} & b_{3,t} \\ c_{1,t} & c_{2,t} & c_{3,t} \\ d_{1,t} & d_{2,t} & d_{3,t} \end{pmatrix} \begin{pmatrix} gdp_{t-1} \\ inf_{t-1} \\ tot_{t-1} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \\ \varepsilon_{3,t} \end{pmatrix}.$$

Putting in vector form, the previous equations now become VAR(1) of

$$\begin{aligned} y_{j,t} &= A + B y_{j,t-1} + \varepsilon_{j,t} \\ E_{j,t-1} y_{j,t} &= A + B y_{j,t-1} \\ E_t y_{j,t+1} &= A(I+B) + B^2 y_{j,t-1} \equiv \hat{y}_{j,t+1} \end{aligned} \tag{2}$$

where forecast $\hat{y}_{j,t}$ is based on data prior to time t and coefficients A and B are estimated over the pre-sample period.

[16] Similarly, change in terms of trade can be viewed as change in index price of exports in terms of index price of exports.
[17] www.globalinsight.com
[18] www.bok.or.kr
[19] www.nso.go.kr

4.3.2 In-Sample Period

Let

$$x_t = \begin{pmatrix} 1 \\ y_{t-1} \end{pmatrix} \quad \theta_{1,t} = \begin{pmatrix} a_{1,t} \\ b_{1,t} \\ b_{2,t} \\ b_{3,t} \end{pmatrix} \quad \theta_{2,t} = \begin{pmatrix} a_{2,t} \\ c_{1,t} \\ c_{2,t} \\ c_{3,t} \end{pmatrix} \quad \theta_{3,t} = \begin{pmatrix} a_{3,t} \\ d_{1,t} \\ d_{2,t} \\ d_{3,t} \end{pmatrix}.$$

The general form of recursive least squares updating is

$$\begin{aligned} \hat{\theta}_{j,t} &= \hat{\theta}_{j,t-1} + \gamma_{j,t} R_{j,t}^{-1} x_t (y_{j,t} - \hat{\theta}'_{j,t-1} x_t) \\ R_{j,t} &= R_{j,t-1} + \gamma_{j,t} (x_t x'_t - R_{j,t-1}) \end{aligned} \tag{3}$$

where $0 < \gamma_{j,t} < 1$ is the learning gain and $\theta_{j,t}$ is the least squares coefficient vector learned by private agents using accessible data up to time t as defined above. In this model, constant gain least squares, which is a a special case of recursive least squares, is used over the various in-sample periods to obtain the learning gain for each in-sample period. The restrictions imposed by constant gain least squares on the general recursive least squares require the second moment matrix $R_{j,t}$ of x_t to be $R^j_{1,t} = \frac{\gamma_j}{1-\gamma_j} P_{j,t-1}$ and $R^j_{2,t} = 1 - \gamma_j$ where $P_{j,t} = E(\theta_{j,t} - \hat{\theta}_{j,t})(\theta_{j,t} - \hat{\theta}_{j,t})'$ is the covariance matrix of $\hat{\theta}_{j,t}$.[20] As the name suggests, constant gain least squares sets its gain parameter to be constant over time, i.e., $\gamma_{j,t} = \gamma_j$, and implies a perpetual learning of the economy. As more data becomes available, the estimate of the parameters is then updated and revised to minimize the constant gain least squares by putting more weight on current data while geometrically discounting past data by the factor of $1 - \gamma_j$.

4.3.3 Out-of-Sample Period

Once in-sample periods are evaluated, out-of-sample forecast performance and the corresponding best fitting constant gain are determined by the minimum mean squared error (MSE) criteria where a MSE of an estimator is computed as

$$MSE(y_j) = \frac{1}{T} \sum_{t=t_0}^{T} (y_{j,t} - \hat{y}_{j,t})^2. \tag{4}$$

The use of MSE is convenient as conditional expectation given in equation (1) is known to give minimum MSE forecasts.[21] The behavior of the resulting optimal gains for real output growth, inflation, and change in terms of trade are then observed in reaction to the crisis.

[20] Branch and Evans (2006).
[21] Evans and Honkapohja (2001).

5 Results and Discussion

The results show a general consensus with the hypothesis, although in varying degrees. Table 1 is organized by the cutoff years of the in-sample periods and shows a comprehensive summary of constant gains for real output growth, inflation, change in terms of trade, and the common gain as well as mean squared errors of their counterparts.[22]

Of the results, the common gain is of particular interest, which is derived from the weighted average of the constant gains for all three variables. The common gain is seen in Figure 4 to linger at its highest point of 0.0640 around the crisis in 1997 and drop sharply thereafter. The graph implies that private agents heavily discounted bygone data before the crisis, but since the shock, put their weights on past and recent data more evenly. This could indicate the strength of the crisis as agents do not dismiss past information as easily as they might have before the structural break. Figures 5 through 7 show the path of the constant gain for individual variables. Both GDP and inflation clearly illustrate a similar experience with that of the common gain in their steep decline of constant gain values immediately after the crisis. GDP gain decreased by 69.39% while inflation gain decreased by 56.93%. The fall in the common gain, 54.69%, was not as high as in output and inflation however, due to the sluggish behavior of terms of trade gain. Figure 7 shows that there was no great change in the gain for terms of trade until 2001 and even then, it continued to stay at a considerably lower level than those of output and inflation. The fact that the terms of trade gain did not show much response to a major economic shock is particularly puzzling as South Korea was a heavily export oriented economy at the time. The explanation of this anomaly is to be a part of future extension of the present paper.

An alternative mean squared error is computed to take into consideration that terms of trade did not play an influential role in the gain response. MSE4, included in Table 1, is taken to be the average of the mean squared errors for GDP and inflation, but not of terms of trade. The best fitting constant is selected by choosing the minimum of the MSE4 values. In-sample period of 1985:1 to 1996:4 turns out to provide the minimum MSE4 of 111.4922 and best fitting common gain of 0.0640. This optimal gain agrees with the estimated value of 0.02 in Milani (2005) and between 0.01 and 0.40 in Orphanides and Williams (2005) as discussed in Molnar and Santoro (2005). The result can also be seen explicitly in Figure 11 and implicitly in Figures 8 and 9, as MSE for GDP and inflation have opposite slopes from each other, with 1996 to be the approximate year with the least average of the two MSE values. Both constant gains for output and inflation decreased after the crisis. It should be noticed, however, that the value of MSE for inflation rose while it fell for output. This suggests that there must have been a greater fluctuation in inflation rate than real GDP growth and this indeed is validated in the graphs of their raw data in Figures 1 and 2. It can also be explained by noting that the average post-crisis gain is 0.0693 for inflation, but only 0.0192 for GDP. Though larger gains may enable faster learning of the structural change, they also

[22]For brevity of the terms, they will now be simply called output (or GDP), inflation, and terms of trade.

have the potential to produce greater variance as can be seen in this case.[23] Though it will not be examined in detail until further research, the observation that the mean squared error for terms of trade decreased since the rise in its gain implies that with higher constant gain, that is, more emphasis on latest information compared to past information, the forecast performance of private agents became more accurate. The positive relation between constant gain and MSE for GDP and negative relation for inflation and terms of trade can also be seen in Figures 12 through 14.

To confirm once again the hypothesis that best fitting constant gain does indeed decline after an economic shock, I conduct a simple exercise where the in-sample period is fixed to end in 1995:4 and the out-of-sample period is restricted to be from 1996:1 to 1997:4 only, that is, the out-of-sample will be the duration of the crisis. I then obtain the gain again by setting the in-sample period to be from the year of the crisis to the end of the sample data: 1997:1-2005:4. Table 2 shows the results. The common gain, as well as constant gains for output and inflation, shows a clear decrease as expected, with an exception of the gain for terms of trade as before.

6 Conclusion and Future Extensions

This paper shows that constant gain learning parameters vary across time and particularly when there is a structural break. It was observed that when there is an economic shock, the learning gain exhibits a high peak followed by a sharp drop in value. In the case of South Korea, a significant amount of change stemmed from the impact on the real output growth and its forecasting from the crisis. It is of immediate future interest to investigate further the reasons for variation of behaviors in inflation from real GDP growth and also inflation and terms of trade change from real GDP growth.

In further research, it is my hope to examine the experiences of various countries that have undergone a comparable economic shock from different regions of the world, such as Southeast Asia and Latin America with their financial crisis, as well as ones with different political structures that may affect the credibility of the monetary authority, expectations of the private sector, and vulnerability to particular factors of the economy such as inflation or exchange rates. Varying degrees of structural changes among countries and over time would also provide a valuable empirical study on how agents respond to shocks of different significance and enable us to better understand the path of the optimal constant gain learning that could account for the structural change. It would also be interesting to compare the crisis countries with those that have enjoyed relatively more stable economic conditions to see how the optimal gain differs. Cross-country comparison of the recursive forecasting models would not only help to better understand the common economic behavior of private

[23] Milani (2005).

agents of various settings, it would instigate a further exploration of how different factors interact with one another when forecasts are formed.

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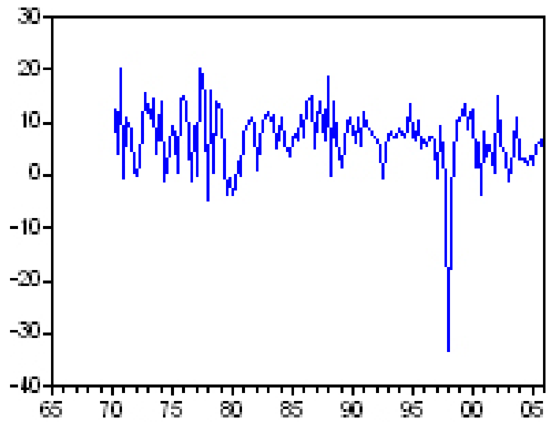

Figure 1: Real GDP Growth

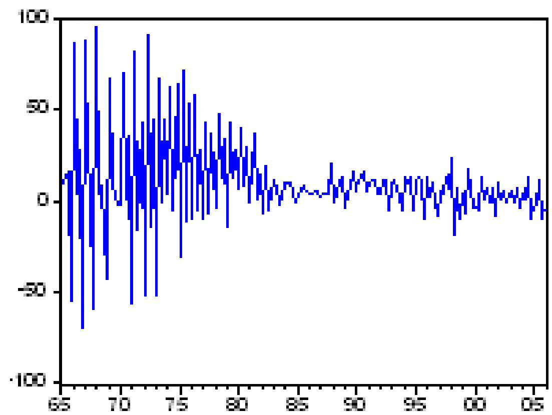

Figure 2: Inflation

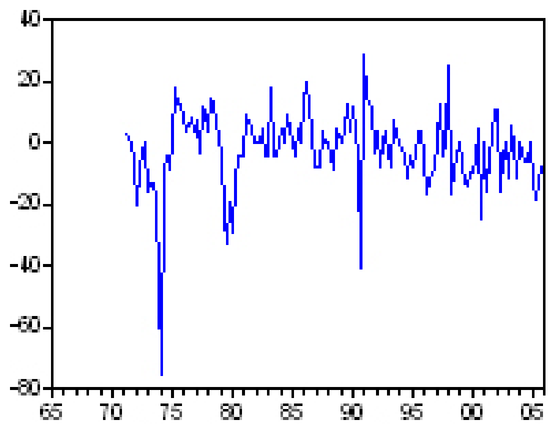

Figure 3: Change in Terms of Trade

In-Sample Period	gny	gnp	gnt	gncomm	MSE1	MSE2	MSE3	MSE4
1985:1 – 1992:4	0.1090	0.1660	0	0.0630	144.5020	190.9169	98.6820	167.7095
1985:1 – 1993:4	0.1060	0.1670	0	0.0640	131.8900	192.3145	102.9245	162.1023
1985:1 – 1994:4	0.1050	0.1560	0	0.0630	114.0238	180.7919	110.2207	147.4079
1985:1 – 1995:4	0.0830	0.1520	0	0.0620	84.1022	163.5698	118.1910	123.8360
1985:1 – 1996:4	0.0780	0.1440	0	*0.0640	78.9063	144.0780	125.3906	**111.4922
1985:1 – 1997:4	0.0490	0.1370	0	0.0640	73.4565	173.3839	128.2231	123.4202
1985:1 – 1998:4	0.0150	0.0590	0	0.0290	22.4042	241.3086	110.1643	131.8564
1985:1 – 1999:4	0.0150	0.0600	0	0.0300	22.6820	278.0221	117.1272	150.3521
1985:1 – 2000:4	0.0160	0.0610	0	0.0320	17.6376	289.6327	100.5753	153.6352
1985:1 – 2001:4	0.0160	0.0610	0.0020	0.0320	16.6393	328.3660	80.6627	172.5027
1985:1 – 2002:4	0.0150	0.0610	0.0060	0.0330	16.9640	425.1572	59.6142	221.0606
1985:1 – 2005:4	0.0160	0.0610	0.0060	0.0340	-	-	-	-

gny: Constant gain for real output growth
gnp: Constant gain for inflation
gnt: Constant gain for change in terms of trade
gncom: Common gain; weighted average of gny, gnp, and gnt
MSE1: Mean squared error for real output growth
MSE2: Mean squared error for inflation
MSE3: Mean squared error for terms of trade
MSE4: Average mean squared error of real output growth and inflation

*Best gain based on **minimum MSE4

Table 1: Constant Gains and MSE

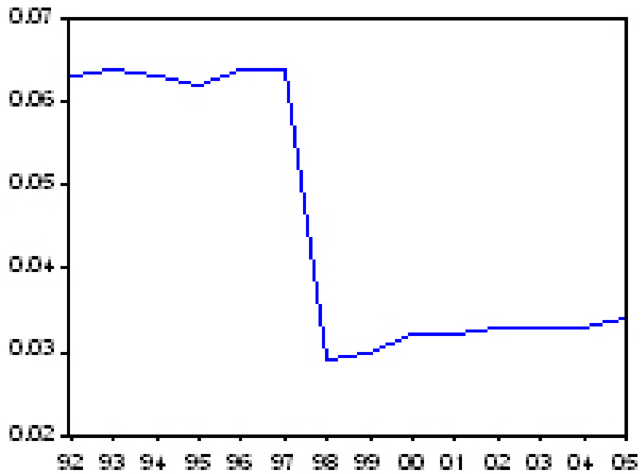

Figure 4: Common Gain

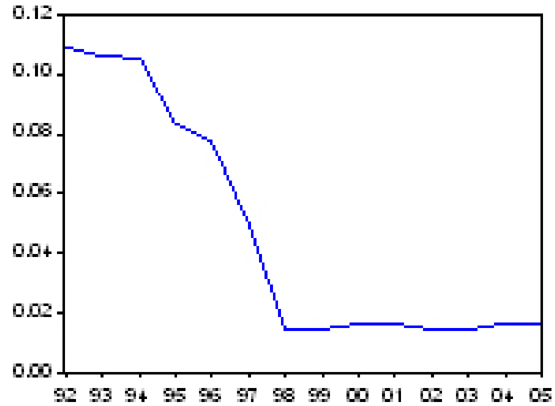

Figure 5: Constant Gain for Real GDP Growth

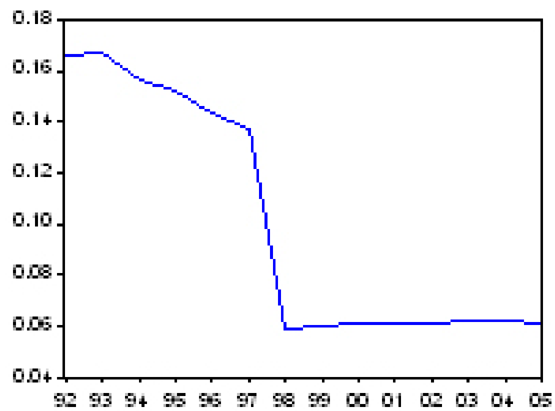

Figure 6: Constant Gain for Inflation

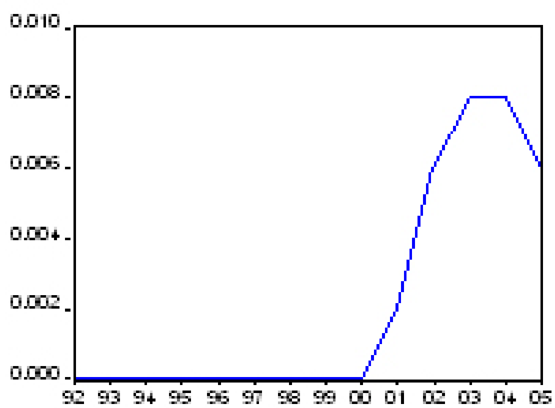

Figure 7: Constant Gain for Change in Terms of Trade

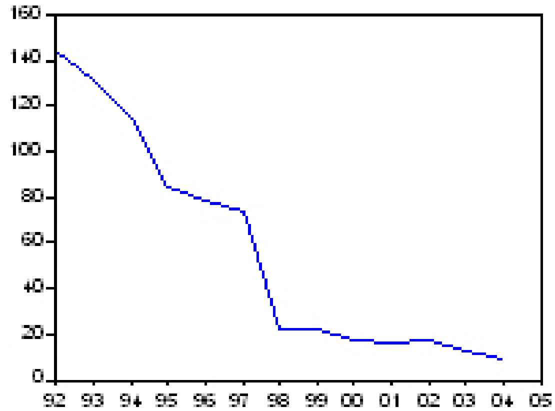

Figure 8: Mean Squared Error for Real GDP Growth

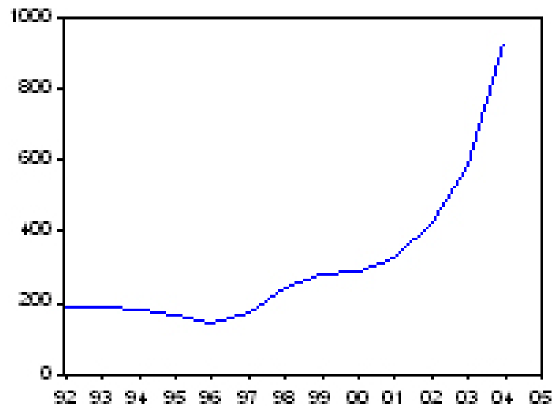

Figure 9: Mean Squared Error for Inflation

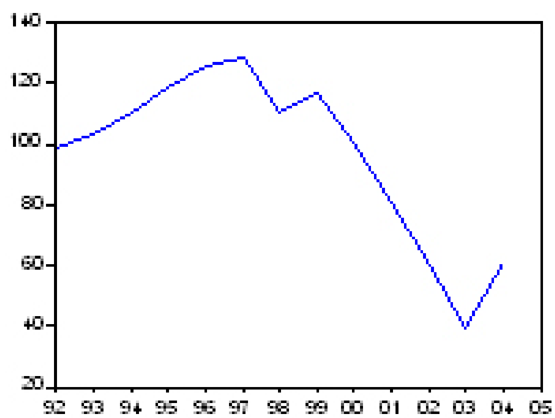

Figure 10: Mean Squared Error for Change in Terms of Trade

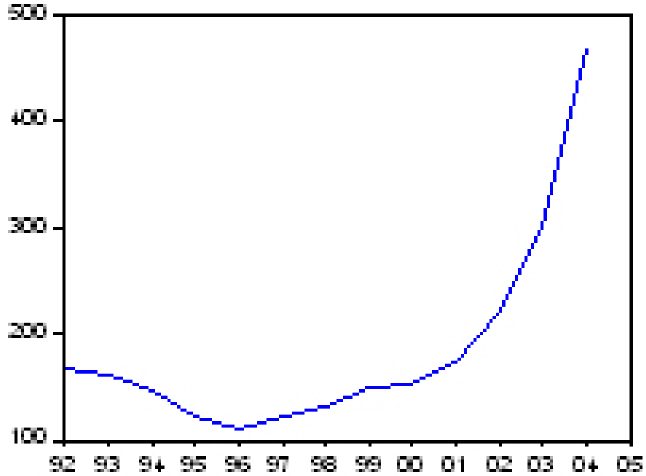

Figure 11: Average MSE for Real GDP Growth and Inflation

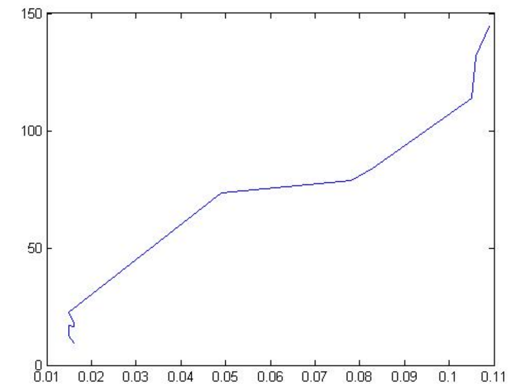

Figure 12: Constant Gain and MSE for Real GDP Growth

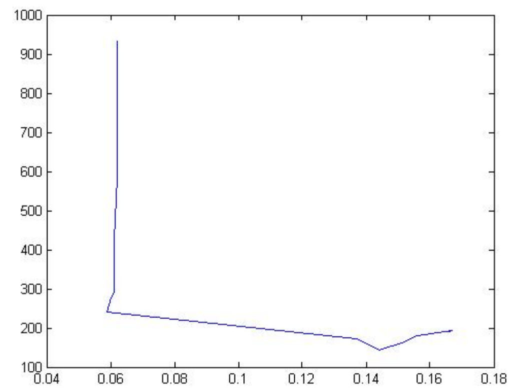

Figure 13: Constant Gain and MSE for Inflation

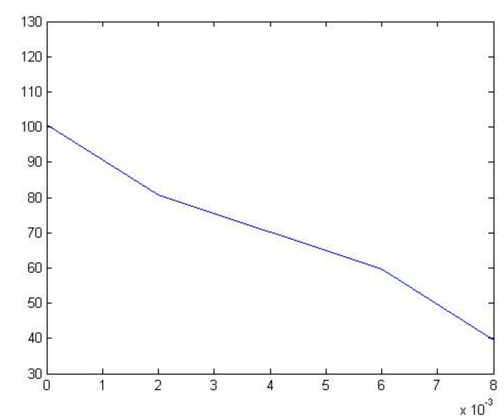

Figure 14: Constant Gain and MSE for Change in Terms of Trade

		gny	gnp	gnt	gncomm	MSE1	MSE2	MSE3
Pre-Sample	**1971:1 – 1984:4**							
In-Sample	**1985:1 – 1995:4**	0.0830	0.1520	0	0.0620	21.3083	237.9466	78.0630
Out-of-Sample	**1996:1 – 1997:4**							
Pre-Sample	**1971:1 – 1996:4**							
In-Sample	**1997:1 – 2005:4**	0.0170	0.1110	0	0.0490	-	-	-

gny: Constant gain for real output growth

gnp: Constant gain for inflation

gnt: Constant gain for change in terms of trade

gncom: Common gain; weighted average of gny, gnp, and gnt

MSE1: Mean squared error for real output growth

MSE2: Mean squared error for inflation

MSE3: Mean squared error for terms of trade

Table 2: Constant Gain in Crisis