Chapter 4

Dynamic Causal Relationships among Macroeconomic Variables in Developing Economies: A Panel Co-Integration/Vector Correction Approach

This chapter applies "developed-country" empirical tests to a large, geographically-dispersed sample of 95 developing countries for the period 1996–2008. The goal is to identify measure, sign and directionalize the dynamic casual relationships linking gross domestic product, money, the interest rate, the price level, the exchange rate, population and the savings rate. Panel co-integration with vector correction reveals statistically significant long-term equilibrium relationships among all variables except population and the savings rate, implying that the main sources of determined output come from the demand side. Results from the error correction model suggest that after a fiscal shock, gross domestic product reverts to its equilibrium within 20 quarters. In contrast, the money supply requires only 8 quarters to revert to equilibrium. The evidence implies that the money supply could potentially be used as one indicator of future movements in gross domestic product in a developing economy. Comparisons of the results from the present study with those from OECD economies suggest that macro-economics has reached a point where differences between "developed" and "developing" economies may be less than those within each bloc. This chapter is developed from the original paper 'Dynamic causal relationships among macroeconomic variables in developing economies: a panel co-integration/vector correction approach'published at International Journal of Intelligent Technologies and Applied Statistics Vol.4 No.1. This full paper is also presented in Appendix A.

4.1. Introduction

Development economics has emerged as a field in economics since the independence of 19th century colonies was achieved from the late 1940s through the early 1960s. Nobel prizes have been awarded to at least five economists for their direct analyses of under-development. These include Lewis (1960,1979) for dualistic models of labour transfer, Kuznets (1973,1977) for the quantification of the structural transformation away from agriculture, Schultz (1971,1980) for theories of human capital and farmer rationality, Myrdal (1973a,1973b) for descriptions of underdevelopment in Asia, and Sen (1933,1997) for formulating the just rights of the poor. But other Nobel laureates, notably Solow (1956), North (1989), Leontief (1973), Frisch(1926), and Tinbergen(1954) have also formulated more inclusive theories with strong implications for poor economies.

This body of pioneering development theories clarifies what makes developing economies different from the European and American models upon which modern macroeconomics is based. It has been empirically validated and nuanced by applications to real-world economies by such applied economists as Chenery (1988), Mellor (1976), Hayami-Ruttan (1971), Kanbur (2006), and Ravallion (2007). To the extent that markets are more imperfect, international trade more fettered, information more subject to principal-agent problems, administrators more corrupt, poverty deeper, the safety net more tattered, and the State more over-involved than in industrialized economies, the domain of economic development studies has been justified, and must still be maintained.

However, it must never be forgotten that the goal of economic development theory is eventually to do itself out of a job; i.e. to help the set of low- and middle-income countries to achieve such high levels of income and economic performance that there will someday no longer be a need for development macroeconomists, but simply macroeconomists. The objective of the present chapter is to take a mid-term progress reading of how far the developing economies have come in the last 60 years towards achieving that goal. We therefore intentionally subject a large sample of low-

and medium-income countries to the same kinds of causal tests among the main macroeconomic aggregates that industrialized countries are subjected to.

This has been done to a modest extent in the past; but each of the handful of studies we cite in this chapter has analyzed only one or two countries at a time, and has often used earlier, less incisive forms of econometric models. In the present chapter, we apply the advanced techniques of vector auto-regression and panel correction to determine how smoothly and integrally a wide range of 95 developing economies are functioning[5]. We then perform meta-analysis of our results with studies from the recent literature on the G12 economies, which themselves have not done particularly well during the past decade in maintaining high growth rates, eliminating corruption and economic crime, avoiding economic crises, liberalizing trade in agricultural products, or balancing the budget. We test the hypothesis that there is virtually no difference between the two sets of economies; or, more bluntly, that the advanced economies also require a lot of attention to development economics.

4.2 Empirical results

4.2.1 The empirical results of the panel unit root test

Tables 4.1 and 4.2 report in summary fashion the panel unit root tests on the relevant variables given in equation (3.3) in Chapter 3. As can be readily seen, most of the tests (with the exception of the LLC test in one case) fail to reject the unit root null hypothesis for *ln GDP, ln Money, ln Interest, ln Exchange* and *ln Inflation* in level form in Table 4.1, but the tests do reject the null of a unit root in difference form in table 4.2. The tables further report the widely used Hadri-Z test statistic, which, as opposed to the aforementioned tests, uses a null hypothesis of no unit root.

However, for *ln Labour* and *ln Save*, most of the tests do reject the null of a unit root in level form, which implies that these two are variables are stationary at level. Thus, the evidence suggests that the variables which is *ln GDP, ln Money, ln*

[5] For this chapter, we will treat the 95 countries as a unified conceptual bloc, but in parallel research we have also tested for significant differences in intercept or slope among 11 distinct regions within those developing economies. Presentation here of those results, as well as their implications for the fine-tuning of macroeconomic policies, would be well beyond the scope of the present chapter.

Interest, ln Exchange and *ln Inflation* do evolve as non-stationary processes and the application of OLS to equations (3.3) above will result in biased and inconsistent estimates. It is, therefore, necessary to turn to panel cointegration techniques in order to determine whether a long-run equilibrium relationship exists among the non-stationary variables in level form.

Table 4.1 :Results of Panel Unit root test base on 6 method test for all variables

	ln GDP	**ln Money**	**ln Interest**	**ln exchange**	**ln inflation**	**ln labour**	**ln save**
Series in level							
Null Hypothesis: Unit root (assumes common unit root process)							
Levin,Lim and Chu	-1.61 (0.05)	-8.59 (0.00)	-38.24 (0.00)	-6.17 (0.00)	6.28 (1.00)	-21.41 (0.00)	-13.53 (0.00)
Breitung	11.48 (1.00)	9.55 (1.00)	3.046 (0.99)	4.88 (1.008)	5.13 (1.01)	1.15 (0.87)	6.04 (1.00)
Null Hypothesis: Unit root (assumes individual unit root process)							
Im,Pesaran and Shin	8.70 (1.00)	2.19 (0.99)	-4.22 (0.00)	1.67 (0.95)	15.42 (1.00)	-12.45 (0.00)	-4.57 (0.00)
Fisher-ADF	92.24 (1.00)	171.91 (0.82)	231.49 (0.01)	177.83 (0.29)	118.50 (1.00)	494.68 (0.00)	303.69 (0.00)
Fisher-PP	110.75 (1.00)	208.01 (0.18)	212.77 (0.048)	180.08 (0.25)	132.80 (0.99)	457.33 (0.00)	277.61 (0.00)
Null Hypothesis: Stationary							
Hadri	18.79 (0.00)	18.68 (0.00)	15.91 (0.00)	21.93 (0.00)	21.04 (0.00)	18.86 (0.00)	22.26 (0.00)

Note: An intercept and trend are included in the test equation. P-values are provided in parentheses. The lag length was selected by using the Akaike Information Criteria.

Table 4.2 :Results of Panel Unit root test base on the 6 method tests at first differences

	ln GDP	ln Money	ln Interest	ln exchange	ln inflation
Series in first differences					
Null Hypothesis: Unit root (assumes common unit root process)					
Levin,Lim and Chu	-27.37 (0.00)	-19.85 (0.00)	-30.03 (0.00)	-20.21 (0.00)	-17.91 (0.00)
Breitung	-4.80 (0.00)	-0.51 (0.30)	-4.73 (0.00)	-2.27 (0.01)	12.37 (1.00)
Null Hypothesis: Unit root (assumes individual unit root process)					
Im,Pesaran and Shin	-12.80 (0.00)	-9.79 (0.00)	-15.58 (0.00)	-7.24 (0.00)	-2.15 (0.02)
Fisher-ADF	467.03 (0.00)	415.09 (0.00)	517.52 (0.00)	323.49 (0.00)	286.35 (0.00)
Fisher-PP	550.09 (0.00)	600.17 (0.00)	756.72 (0.00)	380.97 (0.00)	297.60 (0.00)
Null Hypothesis: Stationarity					
Hadri	21.75 (0.00)	16.85 (0.00)	26.86 (0.00)	16.82 (0.00)	25.88 (0.00)

Note: An intercept and trend are included in the test equation. P-values are provided in parentheses. The lag length was selected by using the Akaike Information Criteria.

4.2.2 The empirical results of panel cointegration test

Having established that money, gross domestic product, interest rate, inflation rate and exchange rate are I(1), we next proceed to test whether a long-run relationship exists between them using Pedroni's (2004) heterogeneous panel cointegration test and the Kao (1999) test. The results for the seven different panel test statistics suggested by Pedroni are reported in Table 4.3. Four of the seven-test statistics suggest that money, gross domestic product, interest rate, level of price and exchange rate are cointegrated at the 5 percent level or better. However, simulations made by Pedroni (1997) showed that, in small samples ($T \approx 20$), the group mean parametric t-test is more powerful than the other tests, followed by the panel v test.

The Kao (1999) test also suggested that money, gross domestic product, the interest rate, the inflation rate and the exchange rate are cointegrated at the 10 percent level.

Table 4.3 : Pedroni's (2004) and Kao(1999) and panel cointegration test

Test Statistic	T-Ratio	P-Value
Pedroni's (2004)		
Panel υ-statistic	3.79***	0.00
Panel Phillip-Perron ρ-statistic	11.85	1.000
Panel Phillip-Perron t-statistic	-9.85***	0.000
Panel ADF t-statistic	-0.77	0.221
Group Phillip-Perron ρ-statistic	15.52	1.000
Group Phillip-Perron t-statistic	-23.47***	0.000
Group ADF t-statistic	-5.66***	0.000
Kao (1999) Test	-1.46*	0.072

Note:*, ** and *** denote statistical significance at the 10 percent, 5 percent and 1 percent levels, respectively.

4.2.3 The empirical results of estimating panel cointegration model

Tables 4.4 and 4.5 report the results of the long- and short-run relationships for money, gross domestic product, the interest rate, the inflation rate, and the exchange rate based on the pool-OLS-,OLS-, DOLS- and GMM-estimators with ln GDP as the dependent variable. The long-run results show that all variables have the expected sign and are statistically significant at the 10percent level or better. Given that the variables are expressed in natural logarithms, the coefficients can be conveniently interpreted as elasticities.

The pool-OLS estimate implies a strong positive association among money supply, the interest rate, the exchange rate and gross domestic product in developing countries. Inflation now has a negative sign and is significant with respect to gross domestic product.

The long run panel cointegration model based on an OLS-estimator shows that money and inflation rate have positive impacts on gross domestic product while the interest rate and the exchange rate have negative impacts at the 1 percent level of statistical significance. The elasticity of GDP with respect to the money supply is greater in absolute terms than that with respect to either the interest rate, the inflation rate or the exchange rate. A 1percent increase in the money supply will increase gross domestic product by 0.45percent.

The long run panel cointegration model based on the DOLS-estimator shows that money and inflation rate exert positive impacts upon gross domestic product while the interest rate and the exchange rate have negative at the 1 percent level of statistical significance. The results indicate that the elasticity of money is greater than the elasticity of either the interest rate, the inflation rate or the exchange rate; and that and a 1percent increase in money leads to a gain in gross domestic product of 0.38 percent.

Table 4.4 : Pool-OLS, Panel OLS and DOLS estimates

	Pool-OLS	**Panel-OLS**	**Panel-DOLS**
Constant	-3.09*** (0.00)	-1.17*** (0.00)	-1.22*** (0.00)
ln *money*	0.83*** (0.00)	0.45*** (0.00)	0.38*** (0.00)
ln int *erest*	0.13*** (0.00)	-0.05*** (0.00)	-0.05** (0.02)
ln inf *lation*	-0.21*** (0.00)	0.22*** (0.00)	0.34*** (0.00)
ln *exchange*	0.02*** (0.01)	-0.13*** (0.00)	-0.14*** (0.00)
Δ(ln *money*(−1))			0.20*** (0.00)
Δ(ln int *erest*(−1))			0.07*** (0.00)
Δ(ln inf *lation*(−1))			0.01 (0.67)
Δ(ln *exchange*(−1))			0.04 (0.39)
AIC	2.20	-0.04	-0.12
SIC	2.22	0.37	0.38

Note:*** denote statistical significant at the 1 percent level. p-value in parenthesis.

Moreover, the DOLS also portrays the effects of change in the short run. The results indicate that in the short run, the elasticity of money is greater than the elasticity of the interest rate, the inflation rate or the exchange rate; and that a 1percent increase in money supply increases gross domestic product by 0.20percent. However, the DOLS-estimator suggests that the interest rate has a significant impact upon gross domestic product but not with the expected signs.

Comparing Akaike Information Criterion (AIC) and Schwartz's Bayesian Information Criterion (SIC), we can see that AIC suggests DOLS as the better model, while SIC suggests OLS. However, SIC generally penalizes free parameters more strongly than does the AIC. Therefore, following a traditional time-series approach to model selection based on the minimization of Schwartz's Bayesian Information Criterion, the OLS-estimator is preferred to either the pooled-OLS or the DOLS estimator.

Table 4.5 presents regression results when the dependent variable is ln GDP. The results show that there is a statistically significant negative relationship between the exchange rate and gross domestic product; but a statistically significant positive relationship among money supply, the interest rate and gross domestic product. However, the GMM-estimator yields an unexpected sign for the significant impact of the interest rate on gross domestic product. The Dynamic-GMM-estimator suggests that only the money supply and interest rate bear a significant impact upon gross domestic product.

Table 4.5: Result from GMM-estimate

	Panel-GMM	**Panel-Dynamic GMM**
Constant	-3.21*** (0.00)	-5.59*** (0.00)
ln *money*	0.71*** (0.00)	1.02*** (0.00)
ln int *erest*	0.15*** (0.00)	0.41*** (0.00)
ln inf *lation*	0.21*** (0.00)	-0.04 (0.77)
$\ln exchange$	- 0.22*** (0.00)	-0.01 (0.90)
$\Delta(\ln money(-1))$		-1.41*** (0.00)
$\Delta(\ln \text{int} erest(-1))$		-0.49*** (0.00)
$\Delta(\ln \text{inf} lation(-1))$		-0.95*** (0.00)
$\Delta(\ln exchange(-1))$		-0.78** (0.03)

Note: Probability values are in parenthesis;*,** and *** denote statistical significance at the 10 percent ,5 percent and 1 percent levels, respectively.

4.2.4 The empirical results of the panel vector error correction model

The empirical results of the panel vector error correction model are reported in table 4.6. First column in Table 4.6 shows that one period lagged money supply and interest rate have a positive and significant impact on gross domestic product. The one period lagged error correction term is statistically significant at the 10 percent level. This result implies that after a shock to the system, GDP reverts to its equilibrium. The speed of adjustment equals -0.20, which implies that in the presence of one unit deviation from the long run in period t-1, the gap from equilibrium in gross domestic product will close by 20 percent in each period or will take 5 years to revert to long-run equilibrium at 10 percent significantly.

Table 4.6: Panel vector error correction model

Independent Variable	Dependent Variable				
	D(ln GDP)	**D(ln Money)**	**D(ln interest)**	**D(ln exchange)**	**D(ln inflation)**
Error correction term	-0.20*	-0.49***	-0.85*	-0.72***	0.13
	(-1.83)	(-2.61)	(-1.66)	(-2.72)	(0.64)
D(ln GDP(-1))	0.07	-0.35	-0.23	-0.76*	-0.02
	(0.57)	(-1.57)	(-0.65)	(-1.71)	(-0.04)
D(ln Money (-1))	0.12*	-0.03	0.43	0.94***	0.11
	(1.79)	(-0.23)	(1.49)	(3.04)	(0.41)
D(ln interest (-1))	0.09**	0.24***	0.47**	-0.17	-0.15*
	(2.16)	(2.73)	(2.08)	(-1.17)	(-1.85)
D(ln exchange (-1))	0.03	-0.09	-0.30*	0.73***	0.16
	(0.46)	(-0.67)	(-1.93)	(4.69)	(1.37)
D(ln inflation (-1))	0.03	0.05	-0.59**	0.02	-0.23
	(0.47)	(0.34)	(-2.10)	(0.15)	(-0.40)

Note: The t-statistics are shown in parenthesis;*,** and *** denote statistical significance at the 10 percent ,5 percent and 1 percent levels, respectively.

It further appears (2nd column) that the one-period lagged interest rate has positive and statistically significant impacts upon the money supply. Moreover, the error correction term is statistically significant at the 10percent level. The speed of adjustment is equal to -0.49, implying that the presence of a one unit deviation from the long run in period t-1 induces the money supply in each period to return 49 percent of the distance back to long-run equilibrium at 10percent significantly. Both one-period lagged gross levels of price and exchange rates have a positive impact on the interest rate while the once-lagged interest rate has negative impacts (3rd column). The error correction term is significant at the 10percent level. This result implies that after a shock to the system, the interest rate reverts to its equilibrium. The speed of adjustment is equal -0.85, in other words in the presence of a one unit deviation from the long run in period t-1, the interest rate will correct itself by 85 percent in each period toward long-run equilibrium at the 10percent level of significance.

Forth column further indicates that one-period lagged gross domestic product, money supply and exchange rate have positive and significant impacts on the exchange rate, even though the error correction term is statistically significant and the speed of adjustment is -0.72. This implies that the exchange rate will tend back to long-run equilibrium by covering 72 percent of the distance from equilibrium in each period. In terms of last column, interest rate lagged one period has a negative and statistically significant impact upon the level of price. However, the error correction term is not statistically significant.

Based upon these empirical results, we rewrite the conceptual framework (Figure 2.1) as Figure 4.1. There are major forward impacts upon GDP exerted by the money supply, the interest rate (passing through the domestic sector) the exchange rate and the inflation rate. However, the only significant backward linkage is from GDP to the exchange rate (passing through the external sector). Since the money supply, the interest rate structure and the exchange rate are all policy operable, macroeconomic planners in low income countries may be able to better maintain, and hasten the return to, equilibrium through a judicious mix of open-economy policies.

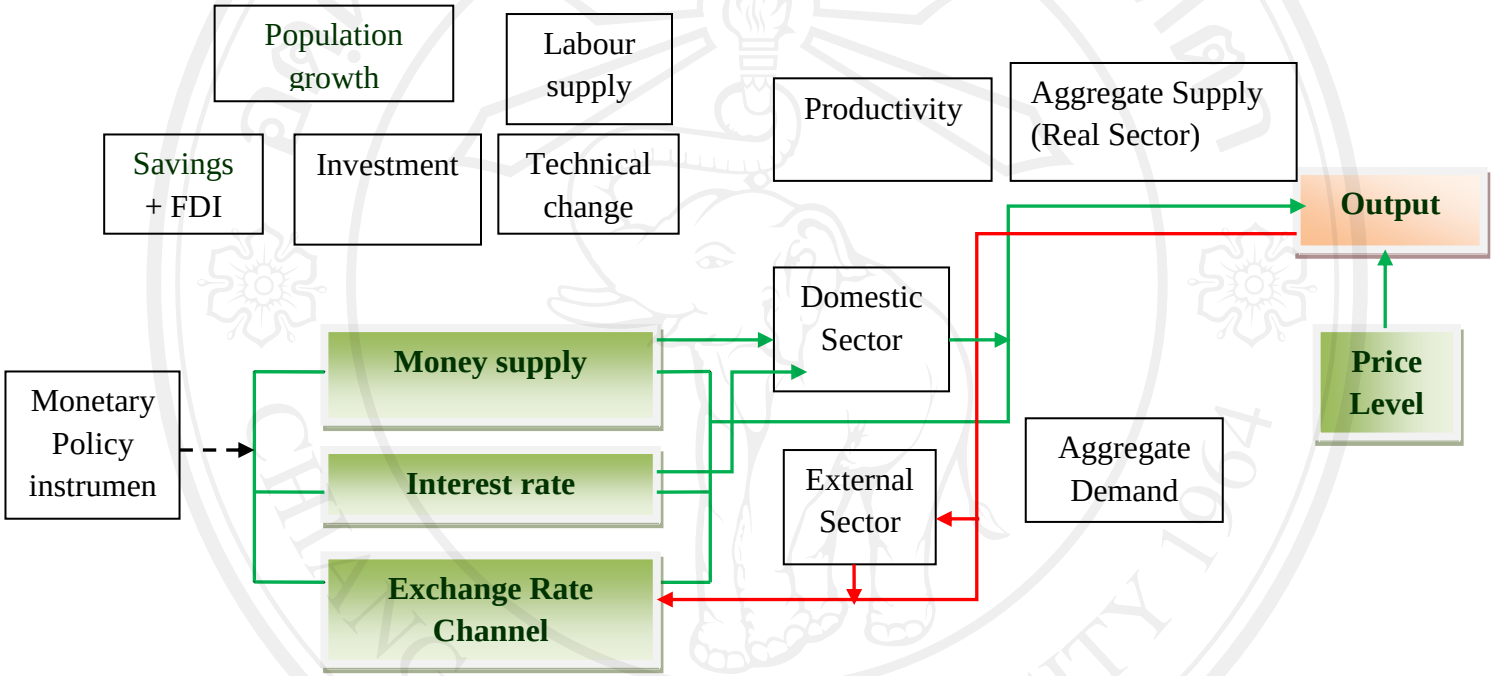

Figure 4.1 Validated significant pathways within the conceptual framework

4.3 Conclusion

The main purpose of this study was to conduct empirical tests to identify, measure, sign and directionalize the dynamic casual relationships linking the macroeconomic variables money, gross domestic product, the interest rate, the inflation rate, the exchange rate, population and the savings rate in a large, geographically-dispersed sample of 95 developing countries. In the framework of this empirical analysis, we applied panel co-integration with vector correction to investigate the existence of causal relationships among the target variables.

The main finding from the panel results establishes a statistically significant long-term equilibrium relationship among all variables (except population and the saving rate), implying that the main sources of determined output come from the demand side. These results are consistent with those from Blanchard and Watson (1986), Blanchard and Quah (1989), and Hartley and Whitt Jr (2003)[6] for the US, UK and European countries. They differ, however, from the findings of Ahmed and Park (1994) and Bergman (1996), which found that shocks on the supply side are the main source of output variance. Thus, although long-term equilibrium exists in all studies, demand is more important in developing economies and the NATO economies, while supply is more important in other developed economies.

The long-term equilibrium results of our study further imply that when a deviation from long-run equilibrium does occur, error correction will make it return to equilibrium, as in the predictions of standard Western macroeconomics. Consistent with the Chicago Monetarist School, the empirical evidence shows that the money supply has greater impacts on gross domestic product than the other variables under study. The error correction model suggests that after a shock to the system, gross

[6] The Hartley and Whitt paper is emblematic of this branch of the literature, in that it attempts to sort out whether macroeconomic fluctuations are permanent or temporary and whether they come primarily from the demand or the supply side. Using a third variable, the interest rate, they break down supply and demand into the two components, permanent and temporary. The authors find that permanent nominal demand shocks are the most important because they destabilize growth. Second in importance are permanent supply shocks that provoke inflation variance and disturb the economy through correlations among output growth, inflation and interest rate changes. Third, temporary demand shocks cause interest rate volatility, which tends to be accommodated through monetary policy.

domestic product reverts to its equilibrium but that the speed of adjustment is only 20 percent per year, so that it will take five years for GDP to revert. In contrast, the money supply requires only 2 years to revert to equilibrium. This finding has strong policy implications for any monetary expansion, since it is found that money supply has greater impacts on gross domestic product than the other nominal variables, such as prices or exchange rates or interest rates in developing country.

These results are in fact even more clear-cut than in the case of most studies on OECD economies. For example, Aksoy and Piskorski (2006) used Granger causality tests to prove the existence of a significant correlation between monetary aggregates and such macroeconomic fundamentals as real output and inflation in the US economy. However, given growing globalization, they had to adjust the measurement of monetary aggregates for US dollar outflows abroad. In so doing, they discovered that domestic money (currency corrected for foreign holdings) may help to predict future real output and inflation. Their innovation of the "standard" theory even for the US economy was necessary to re-establish the Friedman-Schwartz relationships among the money supply, inflation and output, a relationship that had virtually apart in the early 1980s.

Similarly for the United Kingdom, Bhattarai and Jones (2000) found persistent unemployment and inflation consistent with the hysteresis hypothesis; and a trade-off between unemployment and inflation in the period 1975-99. Modeling deviations of output from equilibrium, growth rate of national income, inflation, terms of trade, and exchange rates against key currencies; they determined that shocks on either the demand or the supply side tend to prolong up to 10 quarters in the future before returning to equilibrium. These lags in return to equilibrium are similar to those calculated above (5 to 20 quarters) for underdeveloped economies.

Finally, Caporale *et al* (1998) employed tests of unit roots in the presence of co-integration to draw conclusions about long-run causality among output, money and interest rates in industrialized economies. Although narrow M1 is the best predictor of GDP movements in the bivariate model, interest rates are the most useful in the trivariate model in all industrialized economies except Germany. The authors warn

advanced-country policy makers to give greater weight to interest rates than to monetary aggregates in predicting GDP.

Taken together, the results from the present study and from those cited for the OECD economies suggest that macro-economics has reached a point where differences between developed and “developing” economies may be less than those within each bloc. It will be up to further research to test for significant differences in either intercept or slope for the macroeconomic indicators analyzed in this chapterby sub-category of developing economies (for example, South Asia vs. Latin America or Coastal Africa). Once those differences, if any, are clearly established, it would be desirable to perform the same exercise for the developed macro-economies in order to identify paired subtypes of macro-economy across the two blocs. This would help to harmonize understanding of the strengths and weaknesses of broad categories of economies, and to clarify the implications for improved macroeconomic management at the global level.