# DEVELOPING COUNTRY BUSINESS CYCLES: CHARACTERIZING THE CYCLE AND INVESTIGATING THE OUTPUT PERSISTENCE PROBLEM

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# ABSTRACT

Identifying business cycle stylised facts is essential as these often form the basis for the construction and validation of theoretical business cycle models. Furthermore, understanding the cyclical patterns in economic activity, and their causes, is important to the decisions of both policymakers and market participants. This is of particular concern in developing countries where, in the absence of full risk sharing mechanisms, the economic and social costs of swings in the business cycle are very high. Previous analyses of developing country stylised facts have tended to feature only small samples, for example the seminal paper by Agénor *et al*. (2000) considers just twelve middle-income economies. Consequently, the results are subjective and dependent on the chosen countries. Motivated by the importance of these business cycle statistics and the lack of consistency amongst existing research, this thesis makes an important contribution to the literature by extending and generalising the developing country stylised facts; examining both *classical* and *growth* cycles for a sample of thirty-two developing countries.

One significant finding that emerges is the persistence of output fluctuations in developing countries and the strong positive relationship between the magnitude of this persistence and the level of economic development. The observation of procyclical real wages and significant price persistence indicates the suitability of a New Keynesian dynamic general equilibrium model with sticky prices, to explore this relationship; thus, the vertical production chain model of Huang and Liu (2001) was implemented. This model lends itself to such an analysis, as by altering the number of production stages (N) it is possible to represent economies at different levels of development. There was found to be a strong significant positive relationship between the magnitude of output persistence generated by the model and economic development. However, a very significant finding of this analysis is that the model overestimates output persistence in high inflation countries and underestimates output persistence in low inflation countries. This has important implications not only for this model, but also for any economist attempting to construct a business cycle model capable of replicating the observed patterns of output persistence.

# Table of Contents

# List of Figures

# List of Tables

**Table** **Page Number**

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# Declaration of Authorship

I declare that this thesis is solely the result of my own original work.

Parts of early versions of Chapters Two and Three have been presented, firstly at the University of York, Department of Economics, Research Student Workshops and secondly at a job interview at the Economics Department, University of St. Andrews. No other parts of this thesis have been presented.

Signature ………………………………… Date……………………...

# CHAPTER 1

## *"Introduction"*

Identifying the characteristics and statistical properties (or stylised facts) of business cycles is essential as these often form the basis for the construction and validation of theoretical business cycle models. Furthermore, understanding the cyclical patterns in economic activity, and their causes, is important to the decisions of both policymakers and market participants. This is of particular concern in developing countries where, in the absence of full risk sharing mechanisms, the economic and social costs of swings in the business cycle are very high.[1] Consequently the design of macroeconomic stabilization policies remains a critically important policy objective in many developing countries, for which a detailed understanding of the business cycle and the interaction between policies and the cycle is crucial.

In 1990, Kydland and Prescott established the first set of *stylised facts* for business cycles in the developed world, based on their research into the US business cycle. This led to a burgeoning of literature freshly interested in the statistical properties of business cycles. The business cycles examined in this literature are known as growth cycles, extending from the work of Lucas (1977), and defined by Kydland and Prescott (1990) as "*the deviations of aggregate real output from trend*" (1990, p.4). Subsequent seminal papers by Harding and Pagan (2001, 2002 and 2006) and McDermott and Scott (1999) re-awakened the interest in *classical* cycles. *Classical* cycles are defined as the sequential pattern of expansions and contractions in aggregate economic activity, following the influential work of Burns and Mitchell (1946).

However, the literature extending from both of these strands of business cycle research predominantly concentrates on the business cycles of industrialised countries. A noticeable exception to this pattern is the seminal paper by Agénor, McDermott and Prasad (2000), which established a set of stylised facts for the business cycles of

[1] For example, most developing economies encompass significant capital and credit market imperfections, causing difficulties in portfolio diversification and borrowing, respectively. Thus, consumption and income smoothing over the course of the business cycle are hindered at both the household and country level.

developing countries.[2] This was followed by a number of papers looking at developing countries, such as Rand and Tarp (2002), Neumeyer and Perri (2005) and Aguar and Gopinath (2007). There has also been a surge in papers examining the *classical* cycles of developing countries, notably Cashin (2004), Du Plessis (2006) and Calderon and Fuentes (2006).

Consequently, the knowledge of developing country business cycles is expanding. However the majority of these papers have remarkably small data sets, for example, Agénor *et al.* (2000) have a sample of twelve middle-income countries, Rand and Tarp (2002) have fifteen, whilst Neumeyer and Perri (2005) have only five developing countries in their sample.[3] A fundamental feature that is clearly apparent from reviewing these papers is that there is not the same consistency of findings as for the industrialised countries; only some of the stylised facts reported in Agénor *et al.* (2000) are similarly reported in the subsequent literature and there are fewer consensuses between countries. As such, the results are subjective and clearly depend on the countries chosen for inclusion in the particular study. Based on this inconsistency, it is evident that the small samples that have been employed necessitate that the findings are weak at best and cannot be used to provide an overall picture for the features of developing country business cycles.

Consequently, this thesis intends to examine whether these business cycle *facts* hold for a much larger sample of developing countries, or whether they are robust only for specific subsets of countries. Furthermore, this thesis intends to construct a much more comprehensive set of business cycle characteristics and statistical properties for use by policymakers and in subsequent theoretical modelling of developing country business cycles.

For a set of thirty-two developing countries, plus the United Kingdom, the United States and Japan as developed country benchmarks, the existing developing country business cycle characteristics and statistical properties are re-examined. Furthermore, the set of stylised facts is extended to include the concordance of *classical* cycles; the persistence of output, prices, wages and real exchange rates; and the cross-correlation of output between countries. The developing countries in the sample were selected primarily on the basis of data availability, and to ensure the data set is both geographically representative and

[2] Developing countries is used throughout this thesis as a general classification of both developing and emerging market economies.
[3] Noticeable exceptions to this rule are papers by Pallage and Robe (2001) and Bulir and Hamann (2001), which have 63 and 72 developing countries, respectively, in their samples. However, these concentrate purely on stylised facts relating to foreign aid.

representative of developing countries at different stages of economic development. As such, of the thirty-two developing countries, five are African[4], four are North African[5], nine are Latin American[6], eight are Asian[7] and six are Eastern European[8].

A number of significant empirical findings emerge from this analysis. Firstly, business cycles in developing countries are not, as previously believed, significantly shorter than those of developed countries. This finding is particularly significant as if justifies the use of the same smoothing parameter, when applying the Hodrick-Prescott (HP) filter (Hodrick and Prescott, 1997) to detrend the time series data, for both developed and developing countries.

Secondly, with the exception of the Latin American countries, the volatility of prices and wages are similar to those of the developed countries. Furthermore, there is found to be tendency for those developing countries with countercyclical CPI to also exhibit countercyclical inflation and vice versa, which substantiates the suggestion put forth by Agénor *et al*. (2000) and Rand and Tarp (2002).[9] Real wages, however, are procyclical for both developing and developed countries. This has significant implications for the choice of theoretical business cycle model; for example, procyclical real wages are key predictions of both Real Business Cycle models with technology shocks and New Keynesian models with imperfect competition and countercyclical mark-ups.[10]

Thirdly, real interest rates are, on average, weakly procyclical in developing countries, not countercyclical as previously reported; this holds only for the Latin American economies. This finding is particularly significant as there have been several recent papers that incorporate this feature into theoretical models of emerging market business cycles, including Neumeyer and Perri (2005), Uribe and Yue (2005), Aguiar and Gopinath (2006) and Arellano (2008). Furthermore, real interest rates are, on average, less volatile than in the developed countries; this also contradicts the previous literature.

[4] Cote d'Ivoire, Malawi, Nigeria, Senegal and South Africa.
[5] Israel, Jordan, Morocco and Tunisia.
[6] Argentina, Barbados, Brazil, Chile, Colombia, Mexico, Peru, Trinidad and Tobago, and Uruguay.
[7] Bangladesh, Hong Kong, India, South Korea, Malaysia, Pakistan, the Philippines and Turkey.
[8] Hungary, Lithuania, Macedonia, Romania, the Slovak Republic and Slovenia.
[9] Agénor *et al*. (2000) find that of their 12 developing countries, four countries exhibit countercyclical prices and inflation, whilst three exhibit procyclical prices and inflation. Rand and Tarp (2002) find that of their 15 developing countries, seven countries exhibit countercyclical prices and inflation, whilst two exhibit procyclical prices and inflation. This analysis finds that of the 32 developing countries analysed, fifteen countries exhibit countercyclical prices and inflation, whist nine exhibit procyclical prices and inflation; see Table 3.6.
[10] For a discussion of real wage cyclicality and theoretical modelling see Abraham and Haltiwanger (1995).

Fourthly, broad money, which is procyclical in the industrialised countries, is either weakly procyclical or acyclical in the developing countries. This is consistent with the previous literature. Moreover, there is evidence that money leads the cycle in numerous developing economies, and thus that monetary shocks are an important source of business cycle fluctuations in these countries. Interestingly, broad money is found to be, on average, three to four times more volatile than output in the African and Latin American countries, whilst it is, on average, only fifty percent more volatile than output in the Asian, Eastern European and industrialised countries. This result contradicts the finding of Rand and Tarp (2002), that developed and developing countries exhibit the same relative volatility of broad money. However domestic credit, which is thought to fulfil an important role in determining investment, and hence economic activity, in developing economies, is found to lag, rather than lead, the cycle, thus implying that fluctuations in output influence credit rather than credit influencing the business cycle. This finding is significant as previous analyses by Agénor *et al*. (2000) and Rand and Tarp (2002) indicated that correlations between output and private sector credit peak at zero lag.

Fifthly, an interesting distinction between developed and developing countries emerges when examining the relationship between terms of trade and the business cycle; the developed countries exhibiting countercyclical terms of trade, whilst the majority of developing countries exhibit strongly procyclical terms of trade. This finding corroborates the results of both Agénor *et al*. (2000) and Rand and Tarp (2002).

A final key empirical finding is that developing country business cycles are characterised by significantly persistent output fluctuations; however, the magnitude of this persistence is somewhat lower than for the developed countries. Furthermore, prices and nominal wages are found to be significantly persistent in almost all of the developing countries. This finding is particularly important, because it justifies the use of theoretical models with staggered prices and wages for the modelling of developing country business cycles.

This last empirical finding is of particular importance in light of one of the central issues concerning macroeconomists in recent years: the construction of dynamic general equilibrium models in which monetary policy shocks generate persistent output fluctuations without prices that are set for exogenously long periods. However, whilst much work has been carried out on modelling this empirical feature for the industrialised countries, little, if any, theoretical work has examined this in the context of developing country business cycles.

Returning to the stylised facts, it was revealed that almost all of the thirty-two developing countries exhibited significant output and price persistence. However, this persistence was of a slightly lower magnitude than that observed in the developed countries, with a general pattern emerging of greater persistence in more economically developed countries. Thus, before any theoretical modelling, this relationship between output persistence and economic development was further examined.[11] As expected, this revealed a significant positive relationship between output persistence and economic development.

Many theoretical models have been proposed to examine the issue of output persistence in the industrial countries, especially in the United States. This body of work originates from the seminal papers of Taylor (1980) and Blanchard (1983) who examine output persistence in the context of staggered price and wage contracts. Their intuition is extended to a general equilibrium model in the influential work of Chari, Kehoe and McGrattan (2000). However, rather surprisingly, they find that a staggered price mechanism is, by itself, incapable of generating persistent output fluctuations beyond the exogenously imposed contract rigidity.

Thus, the need for an alternative specification of the sticky price model became apparent and, amongst other suggestions,[12] a number of papers expressed the importance of input-output structures in the transmission of business cycle shocks. For example, Bergin and Feenstra (2000) combine the use of translog preferences, rather than the usual CES preferences, and a simple input-output production structure, as proposed by Basu (1995), where an aggregate of differentiated products serves as both the final consumption good and as an input into the production function of each firm. These two features interact in a positive way and generate significant endogenous output persistence, although this level remains considerably below that observed in the data.

A significant advancement then arises from the vertical input-output mechanism of Huang and Liu (2001). In this model, the production of a final consumption good involves multiple stages of processing and, in order to generate real effects of a monetary shock, prices are staggered among firms within each stage. The input-output structure is fashioned through producers, at all but the initial stage, requiring inputs of labour and a composite of goods produced at earlier stages. Through the input-output relations across

[11] The persistence of output was estimated as the half-life of output (in months). This was calculated for all 32 developing countries, plus the developed country benchmarks (the United Kingdom, the United States and Japan).

[12] Including the application of translog, rather than CES, preferences, e.g. Bergin and Feenstra (2000); the importance of wage staggering, e.g. Huang and Liu (2002); and the inclusion of firm specific capital, see Nolan and Thoenissen (2005) for example.

stages and the staggered prices within stages, the model is capable of generating persistence output fluctuations in response to monetary policy shocks. This feature also enables the model to replicate the observed pattern of dampening price adjustment, as documented by Clark (1999). Furthermore, as production chain length increases, movements in the price level decrease, and fluctuations in aggregate output become increasingly persistence.

The vertical input-output structure of the Huang and Liu (2001) model lends itself to the examination of economies at different levels of development. It is possible to represent countries at different levels of economic development simply by altering the number of stages of production involved. For example, the world's least economically developed countries, such as Malawi, rely very heavily on exports of agriculture and raw materials, whilst having very little industrial production. As such, these countries can be represented by a very simple input-output structure with just one or two stages of production. On the other hand, an emerging market economy, such as Malaysia, will have a much more developed multi-sector economy. Accordingly, more stages can be incorporated in the input-output structure to represent this.

Thus, to further examine the relationship between output persistence and economic development, the structure of the Huang and Liu (2001) model is used to generate persistent output fluctuations, in response to monetary policy shocks, in line with those observed for the developing countries. For this purpose, the model parameters, and most importantly the number of production stages, were calibrated for seventeen developing countries at different stages of economic development,[13] and also for the United Kingdom, the United States and Japan.

The remainder of this thesis is structured as follows: Chapter 2 analyses the *classical* business cycle for thirty-two developing countries, examining the duration and amplitude of the cycle, and the degree of synchronisation both between the developing country cycle and between the developing and the developed country cycles. Chapter 3 re-visits the business cycle stylised facts, both extending the sample to thirty-two developing countries and extending the set of stylised facts to include output and real exchange rate persistence, and cross-country business cycle correlations. Chapter 4 reviews the existing literature on New Keynesian dynamic general equilibrium business cycle models with

[13] This was reduced from the original sample of thirty-two developing countries due to the availability of data necessary for the calibrations. The included countries are Argentina, Brazil, Colombia, Chile, Hungary, India, Israel, South Korea, Lithuania, Malaysia, Mexico, Peru, the Philippines, the Slovak Republic, Slovenia, South Africa and Turkey. This reduction in the number of countries in no way reduces the validity of the business cycle characteristics and stylised facts established in Chapters 2 and 3 of this thesis.

staggered price and wage setting. Chapter 5 firstly examines the degree of output persistence in developing countries, and its relation to economic development, and secondly examines whether the calibration of the Huang and Liu (2001) model enables the successful capture of the observed patterns of output persistence. Finally, Chapter 6 concludes.

# CHAPTER 2

## *"Developing Country Business Cycles: Analysing the Cycle"*

### 2.1. INTRODUCTION

The business cycle is commonly recognized as the periodic fluctuation of aggregate economic activity. More specifically, as highlighted by McDermott and Scott (1999) and Harding and Pagan (2005), there are two distinct methodologies for the description of business cycles, each lending itself to a completely different style of analysis. The first is the *classical* cycle, which can be defined as the sequential pattern of expansions and contractions in aggregate economic activity. This definition of the business cycle extends from the seminal work of Burns and Mitchell (1946), who state that:

> *"a cycle consists of expansions occurring at about the same time in many economic activities, followed by similarly general recessions, contractions, and revivals which merge into the expansion phase of the next cycle; this sequence of changes is recurrent but not periodic"* (p.3)

The second is the *growth* cycle which can be defined, following Lucas (1977) and Kydland and Prescott (1990), as the deviations of aggregate real output from trend. Analysis of this type of business cycle necessitates that the trend (or permanent component) be removed from the data, so that the cyclical component can be analysed. It is this cyclical component which is considered to be the *growth* cycle. This chapter is concerned with characterising and analysing the classical business cycle of developing countries, whilst the subsequent chapter examines the growth cycle and the associated stylised facts.

Central to the classical business cycle approach is the identification of a set of turning points, which separate the periods of expansion and contraction. This requires the application of a dating algorithm, such as the Bry and Boschan (1971) algorithm. The Bry-Boschan algorithm detects local maxima (peaks) and minima (troughs) for a single monthly (deseasonalized) reference series, typically real GDP, subject to certain censoring rules. Between a peak and a trough of economic activity an economy is in a contractionary phase (a recession), whilst between a trough and peak of activity an economy is in an expansionary phase (a boom). Harding and Pagan (2002) modify the algorithm to enable the dating of quarterly data.

Once the turning points have been identified, the characteristics of the business cycle, such as the duration and amplitude of the phases, can be analysed. Furthermore, since at any point in time the series can only be in one of two states, expansion or contraction, this provides a binary variable through which the cyclical patterns of two series can be compared. Harding and Pagan (2002) identify this feature of the data and propose a concordance statistic to measure the degree of synchronisation between two business cycles. This statistic is quantified by measuring the proportion of time that both series are in the same cyclical phase. A later paper, Harding and Pagan (2006), provides the methodology to test the statistical significance of the concordance statistic.

The influential work of Harding and Pagan (2002, 2006) on classical cycles has stimulated a burgeoning literature on developing country business cycles; notably Rand and Tarp (2002), Cashin (2004), Du Plessis (2006) and Calderon and Fuentes (2006). However, these typically examine only small groups of developing countries; Rand and Tarp (2002) analyse fifteen developing countries, Cashin (2004) examines six Caribbean economies, Du Plessis (2006) looks at just seven economies and Calderon and Fuentes (2006) consider seven Latin American countries and seven Asian economies. This chapter aims to extend the current literature, by examining the business cycle characteristics and synchronicity for a much larger set of thirty-two developing countries. Furthermore, the US, the UK and Japan are included; this provides benchmarks upon which to compare the characteristics of the developing country cycles and also to examine the degree of synchronisation between developed and developing countries.

Section two briefly reviews the findings of the developing country literature on classical business cycles. Section three details the methodologies employed in this analysis. Section four describes the data. Section five documents the characteristics of the developing country business cycles in terms of duration and amplitude. Section six examines the patterns of the timing of expansions and contractions in the developing country business cycles, and the degree of concordance between these countries. Finally, section seven concludes.

## 2.2. LITERATURE REVIEW

The significant papers of Harding and Pagan (2002, 2006) have provided a new toolkit for the analysis of business cycles, and this has renewed interest in analysing developing country cycles. The key characteristics that these recent papers have identified are outlined below. However, as this is a relatively new econometric toolkit, and due to problems with acquiring quarterly time-series data for many developing countries, the available literature remains sparse.

Rand and Tarp (2002) use the Bry-Boschan (1971) procedure to document the business cycle dates and durations for fifteen developing countries[1] for the period 1980 to 1998. They make the key finding that developing country business cycles are definitely shorter than those of the industrialised countries;

> *"the average duration of business cycles in developing countries (generally between 7.7 and 12.0 quarters) is clearly shorter than in the industrialised countries (between 24 and 32 quarters)"* (Rand and Tarp, 2002, p.2076)

Examining the timings of peaks and troughs, they observe some synchronicity during major events, such as the second oil crisis in 1982, but that the majority of recessions and expansions are country specific. However, they do not consider any statistical measures of the degree of synchronisation. The paper then proceeds to examine the statistical properties of the *growth* cycle, which are not considered in this chapter.

Cashin (2004) examines the key features of Caribbean business cycles[2] (1963:2003) using both *classical* and *growth* cycles and compares these to the cycles of Canada, Germany, the UK and the US. Concentrating on the *classical* cycles, Cashin (2004) reports the following key results. Firstly, Caribbean business cycles are asymmetric, with considerably longer periods of expansion than contraction. This asymmetry is corroborated in the analysis of the cycle amplitude, with the finding that average output decline during contractions is just 3%, whilst average output increase during expansions is 42%. Secondly, that there is evidence that several of the Caribbean countries co-move with Canada[3] and the US[4], suggesting that economic activity in North America has a positive effect on the Caribbean business cycles. This result extends from the correlation analysis of real output. Finally, the concordance statistic suggests that the degree of synchronisation amongst the Caribbean cycles and between the Caribbean cycles and the developed countries is very strong. However,

[1] Côte d'Ivoire, Malawi, Nigeria, South Africa and Zimbabwe, Chile Colombia, Mexico, Peru and Uruguay and India, and India, South Korea, Malaysia, Morocco and Pakistan.
[2] Antigua and Barbuda, Dominica, Grenada, St. Kitts and Nevis, St. Lucia, and St. Vincent and the Grenadines.
[3] Antigua and Barbuda, Grenada, and St. Kitts and Nevis.
[4] Antigua and Barbuda, and Grenada.

> "*the fact that most countries spend a very large proportion of the sample in an expansion phase has biased upward the measured value of concordance*"
> (Cashin, 2004, p.17).

After mean correcting the data and calculating the statistical significance of the concordance statistic, the only significant synchronisation is between the US and the UK. Thus, as Cashin (2004) stresses, it is vitally important to use hypothesis testing procedures to determine the significance of any observed concordance between business cycles.

Du Plessis (2006) examines the classical cycles, derived from quarterly real GDP data (1980 - 2004), for seven emerging market economies.[5] From this, no clear pattern of business cycle duration is found; two of the seven countries exhibit longer cycles than those of the EMU Area, the US or Japan, three have business cycles of similar length to the developed countries, and two have shorter cycles. Although some evidence is found to suggest that the amplitude of both contractions and expansions is greater than that of the developed countries. Du Plessis (2006) does not examine the concordance amongst the emerging market economies, however the concordance between these countries and the EMU Area, the US and Japan is considered and the appropriate statistical significance levels calculated. The key finding from this analysis is that there is little evidence of co-movement between the business cycles of the emerging market economies and the developed economies.

Calderon and Fuentes (2006) identify the turning points in real GDP for fourteen emerging markets[6] (of which seven are Latin American countries and seven are Asian countries). In characterising the cycles, they make the key findings; firstly, that the duration of contraction phases, but not expansion phases, across country groups are very similar, secondly that the Latin American countries experienced more contractions than the Asian countries, and finally that whilst output losses during contractions are larger in emerging market economies than in developed countries, output gains during expansions are greatest in the emerging market economies. They use concordance indices to examine the co-movement of the business cycles, finding high concordance amongst the Asian countries, but little evidence of concordance amongst the Latin American countries. Furthermore, they find that the Asian economies tend to move together with the US and Japan. However, the statistical significance of these concordance statistics is not calculated.

[5] Hong Kong, Israel, Korea, Mexico, Peru, the Philippines and South Africa.
[6] Argentina, Brazil, Chile, Colombia, Mexico, Peru and Venezuela, and Hong Kong, Indonesia, Korea, Malaysia, Singapore, Taiwan and Thailand.

From reviewing these papers, a number of points are apparent. Firstly, the small samples employed in the analyses; yielding results that are not representative across a broad spectrum of developing countries. Secondly, the failure to calculate the statistical significance of the concordance statistic; only Cashin (2004) and Du Plessis (2006) calculate the statistical significance of their results. And finally, the lack of consistency amongst results, especially where the duration of the developing country cycles is concerned. This later point is particularly concerning, as cycle duration is critical to the correct identification of the *growth* cycle and hence the identification of business cycle stylised facts.[7,8]

Thus, this chapter proceeds to conduct an empirical analysis to establish a much more comprehensive set of business cycle characteristics for developing country cycles. In particular, a key aim is to establish the duration of the developing country cycles. Furthermore, the pattern of synchronicity between developing country cycles and between the developing country cycles and the US, UK and Japan will be analysed, and the statistical significance of these relationships calculated.

## 2.3. METHODOLOGY

### *2.3.1. Identification of Turning Points: The Bry-Boschan (1971) Procedure*

Following the seminal work of Burns and Mitchell (1946), the National Bureau of Economic Research (NBER) defines a country's business cycle as a sequence of expansionary and contractionary phases in a large set of series representing the economic activity of that country. These two phases are characterised by turning points (peaks and troughs) in the times series data; an expansionary phase is defined as trough-to-peak, whilst a contractionary phase is defined as peak-to-trough.

> "*The determination of cyclical turning points, which is usually performed on seasonally adjusted time series, is an essential element of the NBER's business cycle analysis*" (Bry and Boschan, 1971, p.2)

[7] The analysis of *growth* cycles requires that the time-series data are filtered to extract the stationary (cyclical) component. In business cycle research the most commonly applied detrending technique is the Hodrick Prescott (1997) filter. This filter requires the selection of a smoothing parameter, and this choice is determined by cycle duration. If developing country cycles are of a similar length to the developed country cycles, then the same smoothing parameter can be applied for all cycles. However, if business cycles in developing countries are considerably shorter than those of the developed countries, as suggested by Rand and Tarp (2002), then this will require the identification of a different smoothing parameter for the developing country cycles.

[8] The business cycle stylised facts for the developing countries will be analysed in Chapter 3.

However, as noted in Rand and Tarp (2002), the classical methodology of Burns and Mitchell and the NBER is complex and analytically demanding. The Bry-Boschan (BB) procedure (Bry and Boschan, 1971) simplifies this methodology, providing an algorithm to determine turning points in a single monthly series, such as real GDP.

**Table 2.1 Procedure for Programmed Determination of Turning Points**

I. Determination of extremes and substitution of values.

II. Determination of cycles in 12-month moving average (extremes replaced)
   - A. Identification of points higher (or lower) than 5 months on either side.
   - B. Enforcement of alternation of turns in selecting highest of multiple peaks (or lowest of multiple troughs).

III. Determination of corresponding turns in Spencer curve (extremes replaced)
   - A. Identification of highest (or lowest) value within $\pm$ 5 months of selected turn in 12-month moving average.
   - B. Enforcement of minimum cycle duration of 15 months by eliminating lower peaks and higher troughs of shorter cycles.

IV. Determination of corresponding turns in short-term moving averages of 3 to 6 months, depending on MCD (months of cyclical dominance).
   - A. Identification of highest (or lowest) value within $\pm$ 5 months of selected turn in Spencer curve.

V. Determination of turning points in unsmoothed series.
   - A. Identification of highest (or lowest) value within $\pm$ 4 months, or MCD term, whichever is larger, of selected turn in short-term moving average.
   - B. Elimination of turns within 6 months of beginning and end of series.
   - C. Elimination of peaks (or troughs) at both ends of series which are lower (or higher) than values closer to the end.
   - D. Elimination of cycles whose duration is less than 15 months.
   - E. Elimination of phases whose duration is less than 5 months.

VI. Statement of final turning points.

Bry and Boschan (1971, p.21; Table 1)

The BB procedure detects local maxima (peaks) and minima (troughs), for a single time series, subject to certain censoring rules.[9] It first identifies major cyclical swings, then delineates in the neighbourhoods of their maxima and minima, and finally narrows the search for turning points to specific calendar dates. Details of the full procedure, including the censoring rules, are provided in Table 2.1.

This procedure was programmed into MATLAB by Rand and Tarp (2002) and is used here with their kind permission; full details of the MATLAB code are provided in Appendix C.

[9] For details of the censoring rules, see Table 2.1.

### 2.3.2. Measuring Cycle Characteristics: Duration, Amplitude

The Bry-Boschan (1971) algorithm locates peaks and troughs in the data; between which the series is either in a contractionary phase (peak-to-trough) or an expansionary phase (trough-to-peak). Following Harding and Pagan (2001), a binary variable $S_t$ is defined which takes on the value 1 when the series is an expansionary phase and zero otherwise. Using this binary variable and the original series $y_t$ it is possible to produce measures of various cycle characteristics, as defined in Harding and Pagan (2001).

The first measures the average duration of the expansion and contraction phases of the cycle. The average duration of an expansion is defined by Harding and Pagan (2001) to be:

$$\hat{D} = \frac{\sum_{t=1}^{T} S_t}{\sum_{t=1}^{T-1} \left(1 - S_{t+1}\right) S_t} \tag{2.1}$$

Where, $\sum_{t=1}^{T} S_t$ measures the total duration of expansions for the series and $\sum_{t=1}^{T-1} \left(1 - S_{t+1}\right) S_t$ measures the number of peaks in the series.

The second measure, measures the average amplitude of expansion and contraction phases. The average amplitude of expansion phases is defined by Harding and Pagan (2001) to be:

$$\hat{A} = \frac{\sum_{t=1}^{T} S_t \Delta y_t}{\sum_{t=1}^{T-1} \left(1 - S_{t+1}\right) S_t} \tag{2.2}$$

Where, $\sum_{t=1}^{T} S_t \Delta y_t$ measures the total change in economic activity during expansions.

Harding and Pagan (2001) note that the possibility of incomplete phases at the beginning and end of the series may cause difficulties with the use of these measures. Thus, in this analysis these measures are only considered for completed phases.

### 2.3.3. Measuring Synchronization: The Concordance Statistic

Following Harding and Pagan (2002) the degree of synchronisation between two *classical* business cycles can be carried out through the application of the concordance statistic. This statistic measures the proportion of time that two cycles are in the same phase (expansion or contraction). Once again a binary variable $S_t$ is defined which takes on the value one when the series is an expansionary phase and zero otherwise.

Let there be two time series, $x_t$ and $y_t$ and define the binary variables $S_{xt}$ and $S_{yt}$. When series $x_t$ is in an expansionary phase, $S_{xt} = 1$, otherwise $S_{xt} = 0$, and similarly when series $y_t$ is in an expansionary phase, $S_{yt} = 1$, otherwise $S_{yt} = 0$. Then, following Harding and Pagan (2002), the degree of concordance is defined as:

$$\hat{I} = T^{-1}\left[\sum_{t=1}^{T} S_{xt}S_{yt} + \sum_{t=1}^{T}(1 - S_{xt})(1 - S_{yt})\right] \quad (2.3)$$

Where, T is the number of observations.

The concordance index $\hat{I}$ measures the proportion of time that the two series, $x_t$ and $y_t$, are in the same phase, with an $\hat{I}$ of unity implying that the two cycles are in the same phase 100 percent of the time.

However, a measure of whether the degree of synchronisation estimated by $\hat{I}$ is statistically significant is also required. The solution to this problem was provided by Harding and Pagan (2006), who suggest using the correlation between $S_{xt}$ and $S_{yt}$ to test for no concordance; where the null hypothesis of no concordance between series $x_t$ and $y_t$ corresponds to a correlation coefficient $\rho_S$ of zero. Further, they state that, under the assumption of mean independence, an estimate of the correlation coefficient $\hat{\rho}_S$ can be obtained from the regression:

$$\frac{S_{yt}}{\hat{\sigma}_{Sx}\hat{\sigma}_{Sy}} = \alpha + \rho_S \frac{S_{xt}}{\hat{\sigma}_{Sx}\hat{\sigma}_{Sy}} + u_t \quad (2.4)$$

Where, $\hat{\sigma}_{Sx}$ and $\hat{\sigma}_{Sy}$ are the estimated standard deviations of $S_{xt}$ and $S_{yt}$, respectively.

The t-statistic associated with $\hat{\rho}_S$ in the above regression can be used to evaluate the statistical significance of the null hypothesis of no concordance between the two series. However, as noted by Harding and Pagan (2006), in order to get the correct t-statistic for $\hat{\rho}_S$ it is necessary to use heteroscedastic and autocorrelation consistent (HAC) standard errors. To this purpose, GMM estimation with a HAC covariance matrix is used; the Bartlett kernel and the Newey and West fixed bandwidth are selected.[10]

## 2.4. DATA DESCRIPTION AND COUNTRY INFORMATION

There are thirty-two developing countries included in this sample, of which there are five African countries (Côte d'Ivoire, Malawi, Nigeria, Senegal and South Africa), four North

[10] This procedure is performed using the statistical package STATA.

African and Middle Eastern countries (Israel, Jordan, Morocco and Tunisia), nine Latin American countries (Argentina, Barbados, Brazil, Chile, Colombia, Mexico, Peru, Trinidad and Tobago, and Uruguay), eight Asian countries (Bangladesh, Hong Kong, India, South Korea, Malaysia, Pakistan, the Philippines and Turkey) and six Central and Eastern European countries (Hungary, Lithuania, Macedonia, Romania, the Slovak Republic and Slovenia). In addition, three developed countries, the United Kingdom, the United States and Japan, are included as benchmarks upon which to compare the results for the developing countries.

The developing countries in the sample were selected primarily on the basis of data availability, and to ensure the data set is both geographically representative and representative of developing countries at different stages of economic development. Table 2.2 provides summary information about the countries included in this analysis, including: GNI per capita and World Bank income classifications, Human Development Index (HDI) scores and UN development classifications, and average GDP and GDP per capita growth rates.

Reliable real GDP data, which is usually used as a measure of the aggregate business cycle, is not available for a large number of developing countries. This is especially prevalent where quarterly data, which is necessary for the analysis of business cycle turning points, is concerned. Thus, following the suggestion of Agénor *et al.* (2000), indexes of industrial production are used as a suitable proxy for the aggregate business cycle:

> *"The manufacturing sector accounts for a significant fraction of total GDP…In addition, because output in the industrial sector roughly corresponds to output in the traded goods sector (excluding primary commodities) and is most closely related to what are traditionally thought of as business cycle shocks, either exogenous or policy determined, we argue that this variable is a reasonable proxy for measuring the aggregate cycle"* (Agénor *et al.*, 2000, p.255)

In this sample of developing countries, the proportion of total GDP which is accounted for by the manufacturing sector varies from an average of 19.6% in Barbados to 46.16% in Trinidad and Tobago, with a sample average of 32.2%.[11] Figure 2.1 shows the composition of GDP for the sample countries, whilst Table 2.3 provides a summary of GDP composition for the regional groupings and for the income groupings.

[11] These are based on averages for the period 1980 – 2005 for the series Industry, value added (% of GDP) from the World Bank World Development Indicators.

**Table 2.2** **Summary Information for Sample Countries**

| | GNI per Capita | | | HDI | | | Average Growth Rate (%) | |
|---|---|---|---|---|---|---|---|---|
| | 1985 | 1995 | 2005 | 1985 | 1995 | 2005 | GDP | GDP per Capita |
| United States | 17,070 | 27,910 | 43,570 | 0.909 | 0.939 | 0.955 | 2.97 | 1.89 |
| United Kingdom | 8,100 | 19,430 | 38,320 | 0.870 | 0.929 | 0.947 | 2.36 | 2.09 |
| Japan | 10,900 | 40,350 | 38,950 | 0.902 | 0.931 | 0.956 | 2.38 | 1.98 |
| **Africa** | | | | | | | | |
| Côte d'Ivoire | 610 | 660 | 820 | ... | 0.456 | 0.480 | 0.76 | -2.54 |
| Malawi | 160 | 160 | 220 | 0.379 | 0.453 | 0.476 | 2.51 | -0.53 |
| Nigeria | 370 | 220 | 620 | ... | 0.450 | 0.499 | 2.84 | 0.14 |
| Senegal | ... | ... | 800 | ... | 0.399 | 0.460 | 2.88 | 0.17 |
| South Africa | 2,420 | 3,740 | 4,810 | 0.680 | ... | 0.678 | 2.19 | 0.15 |
| **North Africa** | | | | | | | | |
| Israel | 6,000 | 14,090 | 20,060 | 0.853 | 0.883 | 0.929 | 4.19 | 1.88 |
| Jordan | 1,990 | 1,560 | 2,490 | 0.638 | 0.656 | 0.764 | 4.68 | 1.03 |
| Morocco | 600 | 1,120 | 2,000 | 0.499 | 0.562 | 0.640 | 3.64 | 1.76 |
| Tunisia | 1,160 | 1,820 | 2,870 | 0.605 | 0.654 | 0.758 | 4.37 | 2.46 |
| **Latin America** | | | | | | | | |
| Argentina | 2,660 | 7,360 | 4,460 | 0.797 | 0.824 | 0.855 | 1.59 | 0.57 |
| Barbados | 4,450 | 7,000 | 9,330 | ... | ... | 0.890 | 1.27 | 1.21 |
| Brazil | 1,570 | 3,740 | 3,970 | 0.694 | 0.734 | 0.805 | 2.46 | 0.75 |
| Chile | 1,420 | 4,340 | 5,930 | 0.762 | 0.822 | 0.872 | 5.11 | 3.55 |
| Colombia | 1,210 | 2,200 | 2,880 | 0.698 | 0.757 | 0.795 | 3.11 | 1.40 |
| Mexico | 2,190 | 3,810 | 8,080 | 0.768 | 0.794 | 0.844 | 2.78 | 1.04 |
| Peru | 960 | 1,990 | 2,660 | 0.703 | 0.744 | 0.791 | 2.13 | 0.36 |
| Trinidad and Tobago | 5,880 | 3,850 | 10,710 | 0.791 | 0.797 | 0.825 | 2.25 | 1.52 |
| Uruguay | 1,510 | 5,540 | 4,820 | 0.783 | 0.817 | 0.855 | 1.51 | 1.19 |
| **Asia** | | | | | | | | |
| Bangladesh | 200 | 310 | 440 | 0.351 | 0.415 | 0.527 | 4.29 | 2.16 |
| Hong Kong | 6,110 | 23,490 | 28,150 | 0.830 | 0.886 | 0.939 | 5.27 | 4.04 |
| India | 300 | 380 | 740 | 0.453 | 0.511 | 0.596 | 5.71 | 3.89 |
| Korea, South | 2,340 | 10,770 | 16,900 | 0.760 | 0.837 | 0.927 | 6.66 | 5.53 |
| Malaysia | 1,950 | 4,030 | 5,200 | 0.689 | 0.767 | 0.821 | 6.28 | 3.69 |
| Pakistan | 370 | 490 | 720 | 0.423 | 0.469 | 0.555 | 5.20 | 2.65 |
| Philippines | 520 | 1,020 | 1,260 | 0.651 | 0.713 | 0.744 | 2.86 | 0.59 |
| Turkey | 1,280 | 2,710 | 6,230 | 0.674 | 0.730 | 0.796 | 4.11 | 2.46 |
| **East Europe** | | | | | | | | |
| Hungary | 1,880 | 4,110 | 10,260 | 0.813 | 0.816 | 0.874 | 1.53 | 1.85 |
| Lithuania | ... | 2,070 | 7,280 | ... | 0.791 | 0.862 | 0.20 | 1.25 |
| Macedonia | ... | 1,710 | 2,810 | ... | 0.782 | 0.810 | -0.35 | -0.47 |
| Romania | ... | 1,470 | 3,920 | ... | 0.780 | 0.824 | 0.72 | 0.96 |
| Slovak Republic | ... | 3,310 | 8,190 | ... | 0.827 | 0.867 | 1.65 | 1.78 |
| Slovenia | ... | 8,500 | 18,060 | ... | 0.861 | 0.918 | 2.36 | 2.49 |

| HDI Classification | | GNI per Capita Classification | | | |
|---|---|---|---|---|---|
| | | | 1985 | 1995 | 2005 |
| Low Human Development | HDI < 0.500 | Low Income | ≤ 480 | ≤ 765 | ≤ 875 |
| Medium Human Development | 0.500 < HDI < 0.799 | Lower Middle Income | 481 - 1,940 | 766 - 3,035 | 876 - 3,465 |
| High Human Development | 0.800 < HDI < 0.899 | Upper Middle Income | 1,941 - 6,000 | 3,036 - 9,385 | 3,466 - 10,725 |
| Very High Human Development | HDI > 0.900 | High Income | > 6,000 | > 9,385 | > 10,725 |

The average GDP and GDP per capita growth rates are calculated from GDP growth (annual %) and GDP per capita growth (annual %), respectively, from the World Bank World Development Indicators (WDI) for the period 1980 to 2005. GNI per capita is GNI per capita (Atlas method, current US$) from the World Bank WDI, and the income classifications are taken from the World Bank GNI per capita Operational Guidelines and Analytical Classifications. Human Development Index (HDI) rankings and classifications are from the UN Human Development Reports. Following the UN classification, all countries with an HDI below 0.900 are classified as developing economies, whilst all countries with an HDI above 0.900 are classified as developed economies.

**Figure 2.1** **Composition of GDP**

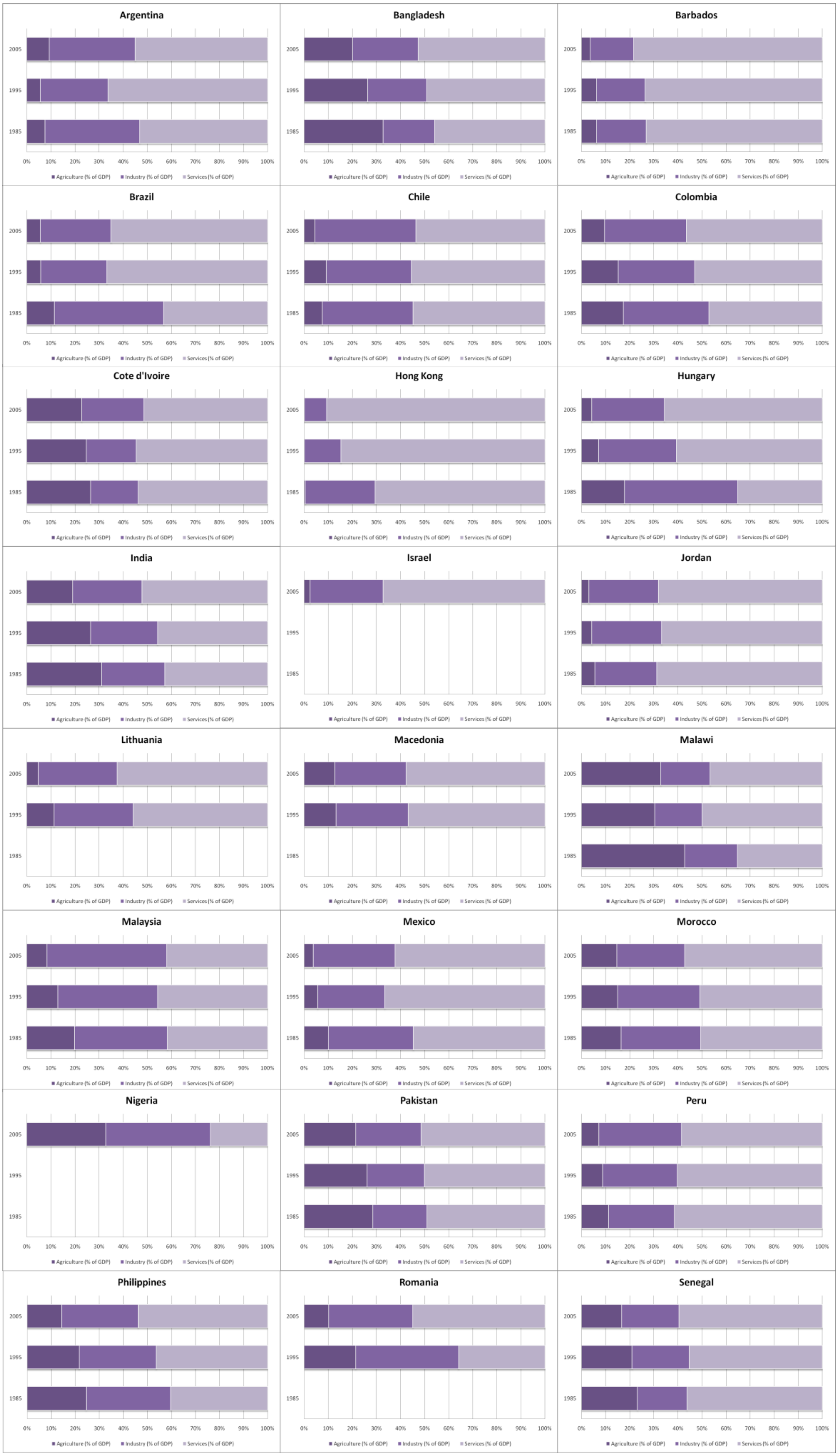


**Figure 2.1** **Composition of GDP (continued…)**


**Table 2.3** **GDP Composition by Region and Income Grouping**

| | Agriculture (% of GDP) | Industry (% of GDP) | Services (% of GDP) |
|---|---|---|---|
| **Africa** | 26.10 | 28.43 | 45.48 |
| | *14.81* | *8.67* | *15.19* |
| **North Africa** | 11.78 | 29.48 | 58.73 |
| | *6.01* | *2.25* | *8.25* |
| **Latin America** | 7.97 | 33.27 | 58.73 |
| | *3.48* | *7.19* | *6.89* |
| **Asia** | 17.67 | 30.09 | 52.24 |
| | *9.95* | *7.96* | *11.34* |
| **Eastern Europe** | 10.27 | 37.96 | 51.77 |
| | *4.87* | *4.16* | *6.09* |
| **Low Income** | 29.72 | 25.48 | 44.80 |
| | *7.34* | *5.83* | *11.49* |
| **Lower-Middle Income** | 12.90 | 31.04 | 56.06 |
| | *5.49* | *2.49* | *7.67* |
| **Upper-Middle Income** | 8.62 | 35.22 | 56.15 |
| | *4.80* | *7.15* | *9.15* |
| **High Income** | 1.99 | 32.20 | 65.81 |
| | *0.42* | *4.64* | *4.87* |

Figures are averages for the period 1980 to 2005. Numbers in italic are standard deviations. Agriculture is agriculture, value added (% of GDP), industry is industry, value added (% of GDP) and services is services, value added (% of GDP) from the World Bank, World Development Indicators.

From Table 2.3 it is clear that the greatest component of GDP, for all countries, is services. Unfortunately, quarterly services data is not available for the majority of countries, and thus cannot be examined in this thesis. However, consistent with the above assertion of Agénor *et al.* (2000), manufacturing production does make up a significant proportion of GDP, exceeding agriculture for all but the poorest economies. Furthermore, manufacturing production makes up the largest proportion of merchandise exports for most of the developing countries. The only exceptions are the African countries, for whom, on average, food and fuel exports exceed manufacturing exports (as a percentage of merchandise exports). Figure 2.2 details the composition of merchandise exports for the developing countries, whilst Table 2.4 summarises the composition of exports for the regional and income groupings.

Thus, this analysis follows the suggestion of Agénor *et al.* (2000) and employs indexes of industrial production as a proxy of the aggregate business cycle. The data comes from the International Monetary Fund (IMF) International Financial Statistics (IFS) database and either manufacturing production (IMF IFS series 66EY) or industrial production (IMF IFS series 66) is employed. The sample period varies depending on the availability of quarterly data for each country; however there is good data coverage for the period from 1980 to 2004 across countries.[12]

Further to this, given the importance of agricultural production for the poorest economies, the analysis is also extended such that the duration of industrial production and agricultural production cycles can be compared. Unfortunately, quarterly agricultural data is only available for a small sub-set of the developing countries included in this study; namely, Brazil, Chile, Colombia, Hungary, India, Lithuania, Malaysia, Mexico, Philippines, South Africa, South Korea, Slovak Republic, and Turkey.

[12] This provides 24 years of data, or 96 quarterly observations. Given the fact that business cycles are estimated to be between 7.7 and 12 quarters for developing economies and between 24 and 32 quarters for developed economies (Rand and Tarp, 2002), this ensures that the time series should include at least three full business cycles for each economy. Obvious exceptions to this are the Eastern European countries, Lithuania, Macedonia, Slovak Republic and Slovenia for which the time series is reduced to the period 1992 to 2005; however this still provides coverage for at least one complete cycle.

**Figure 2.2** **Composition of Manufacturing Exports**

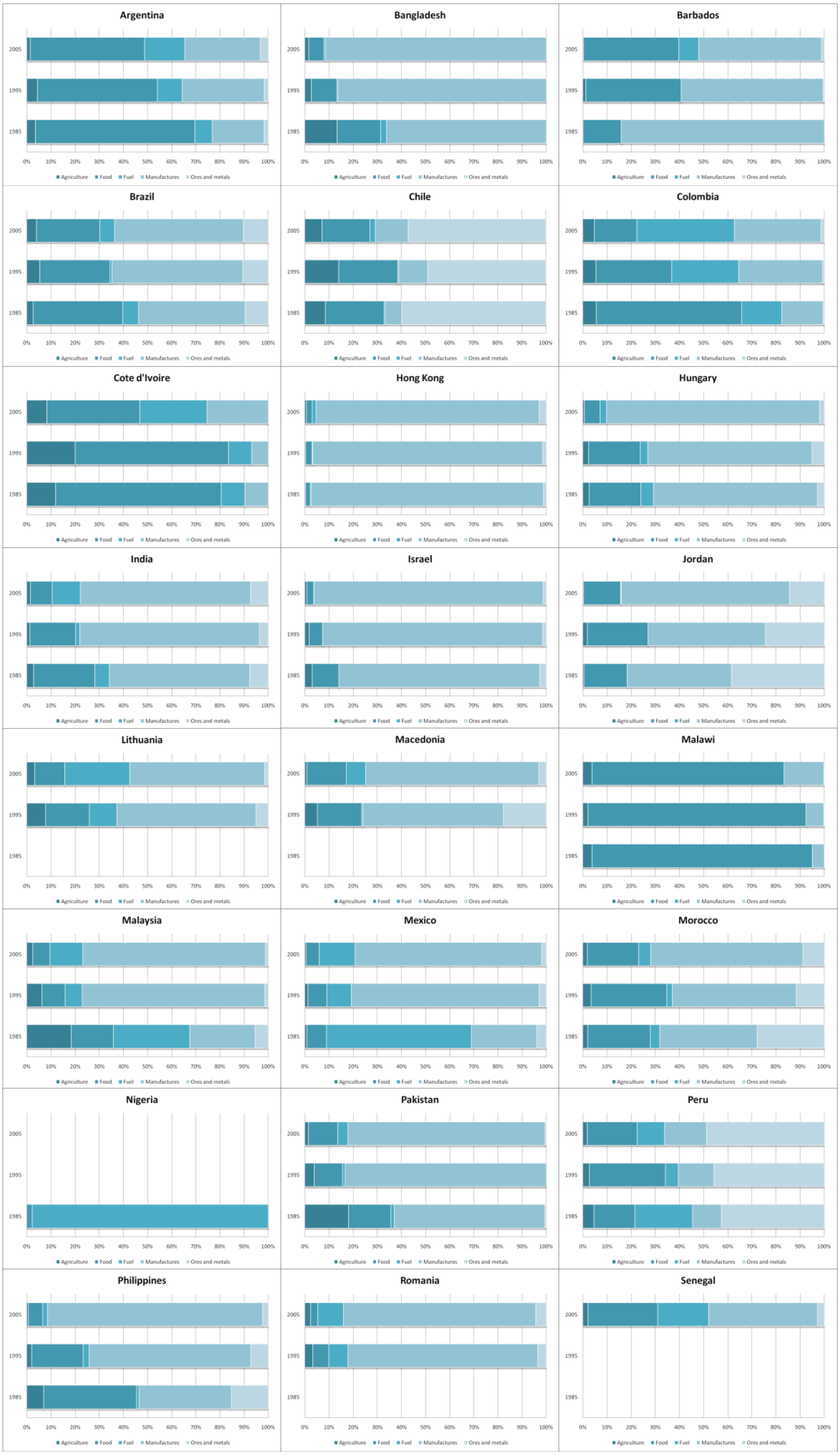


**Figure 2.2 Composition of Manufacturing Exports (continued…)**

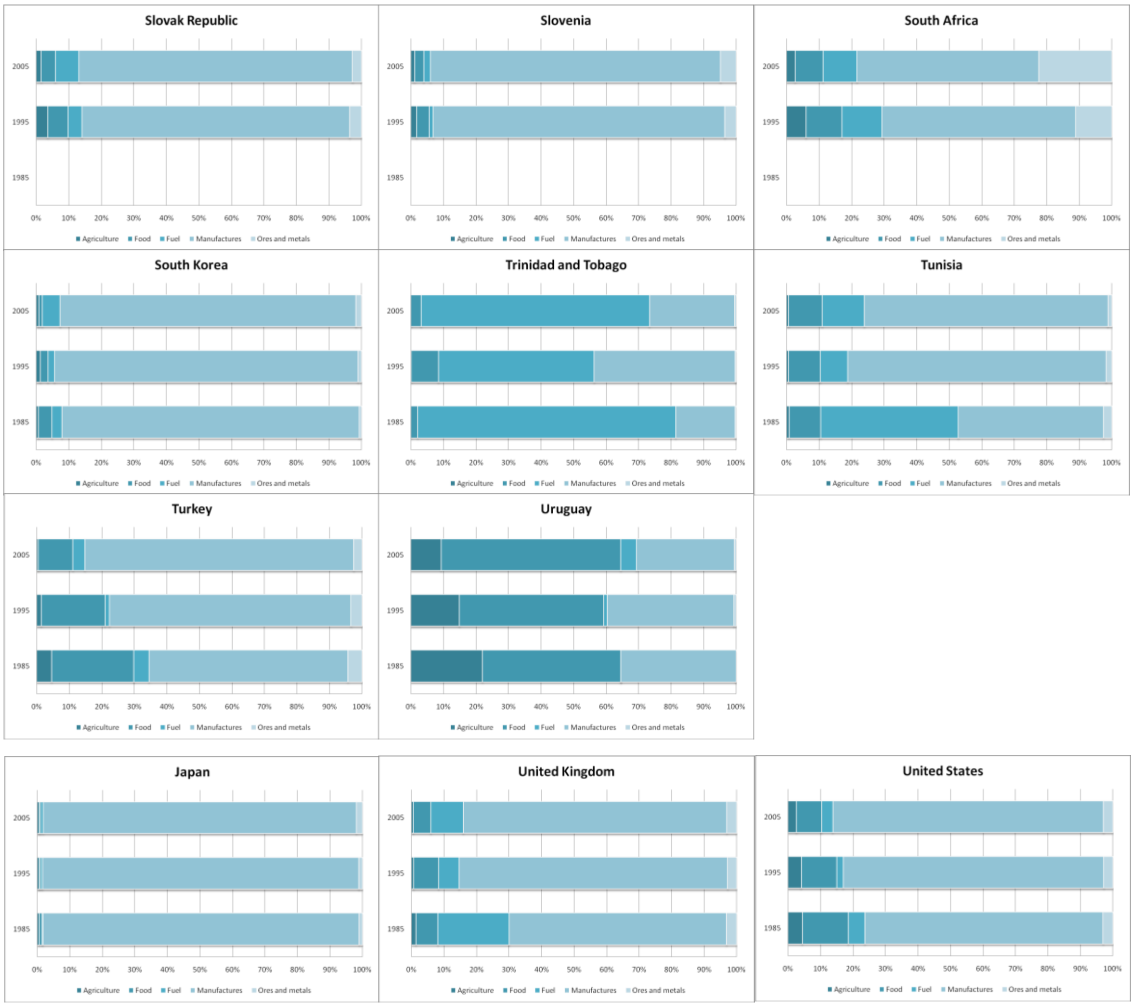



**Table 2.4 Composition of Merchandise Exports by Region and Income Grouping**

| | Agriculture (% of exports) | Food (% of exports) | Fuel (% of exports) | Manufactures (% of exports) | Ores and metals (% of exports) |
|---|---|---|---|---|---|
| **Africa** | 4.52 | 38.17 | 27.29 | 20.34 | 4.33 |
| | *4.72* | *36.06* | *39.25* | *17.60* | *5.86* |
| **North Africa** | 1.53 | 15.13 | 6.10 | 64.36 | 12.63 |
| | *1.03* | *8.34* | *9.91* | *17.19* | *13.47* |
| **Latin America** | 4.80 | 29.37 | 16.95 | 35.23 | 12.05 |
| | *5.34* | *16.28* | *21.02* | *17.03* | *19.40* |
| **Asia** | 4.60 | 12.73 | 3.80 | 73.21 | 2.56 |
| | *4.14* | *7.24* | *4.99* | *13.91* | *2.30* |
| **East Europe** | 2.77 | 10.38 | 6.76 | 75.17 | 4.30 |
| | *1.24* | *6.67* | *6.10* | *10.76* | *2.44* |
| **Lower Income** | 5.22 | 32.37 | 19.42 | 40.36 | 2.11 |
| | *4.29* | *30.97* | *34.65* | *33.52* | *3.60* |
| **Lower-Middle Income** | 1.96 | 18.55 | 6.45 | 51.49 | 17.38 |
| | *1.07* | *5.44* | *7.89* | *18.81* | *14.71* |
| **Upper-Middle Income** | 4.05 | 18.00 | 11.03 | 59.03 | 5.67 |
| | *4.35* | *15.94* | *15.78* | *24.67* | *11.41* |
| **High Income** | 1.69 | 6.31 | 4.56 | 82.01 | 2.19 |
| | *1.65* | *5.40* | *5.15* | *11.24* | *0.94* |

Figures are averages for the period 1980 to 2005. Numbers in italic are standard deviations.
Agriculture is agricultural raw materials exports (% of merchandise exports), food is food exports (% of merchandise exports), fuel is fuel exports (% of merchandise exports), manufactures is manufactures exports (% of merchandise exports) and ores and metals is ores and metals exports (% of merchandise exports) from the World Bank, World Development Indicators.

## 2.5. CYCLE CHARACTERISTICS

### *2.5.1. Duration*

Tables 2.5(a) and 2.5(b) summarises the average duration (in quarters) of the business cycle by regional and income grouping, respectively. In looking at this, it is particularly interesting to examine the finding of Rand and Tarp (2002), namely that business cycles in the developing countries are significantly shorter than those of the developed countries.

**Table 2.5(a) Average Business Cycle Duration (By Region)**

| Region | Average Duration (in quarters) | | |
|---|---|---|---|
| | Expansion | Contraction | Cycle |
| US, UK and Japan | 15.9 | 4.7 | **20.1** |
| Africa | 8.3§ | 5.9 | **14.4***§* |
| North Africa | 20.0 | 5.1 | **22.2** |
| Latin America | 12.0 | 5.1 | **14.2***§* |
| Asia | 26.4 | 4.7 | **30.4** |
| Eastern Europe | 14.4 | 7.7 | **22.5** |

**Table 2.5(b) Average Business Cycle Duration (By Income)**

| Region | Average Duration (in quarters) | | |
|---|---|---|---|
| | Expansion | Contraction | Cycle |
| High Income | 14.8 | 4.8 | **19.7** |
| Upper Middle Income | 16.6 | 6.0 | **20.4** |
| Lower Middle Income | 16.6 | 4.9 | **19.4** |
| Low Income | 16.0 | 5.2 | **21.3** |

Note that significant differences from the developed country benchmarks (the United States, United Kingdom and Japan) are denoted by *§* ($p < 0.05$) and **§** ($p < 0.01$). Average duration of the cycle is the average of completed cycles, measured both from peak to peak and from trough to trough.

The results in Tables 2.5(a) and 2.5(b) indicate that there is no clear significant difference between the developing country and developed country business cycles. The African and Latin American regions display significantly shorter cycles than the rest of the sample. However, the North African, Eastern European and developed countries have very similar length cycles, whilst the Asian countries have substantially longer cycles that the rest of the sample. Furthermore, comparison between income groups reveals no significant differences in cycle length.[13]

However, there is a rather simple explanation for this. Besides the relatively small sample, Rand and Tarp (2002) have compared their results based on industrial production

[13] However, the average duration for the low income group is skewed upwards by the extremely long duration observed in the Indian data; see Table 2.6 for country specific duration statistics.

for the developing countries with the standard results for developed country cycles, but these developed country cycles will have been calculated using real GDP not real industrial production! When both developing and industrialised country business cycles are compared using the same variable, real industrial (or manufacturing) production in this case, it is clear that developed country business cycles are not significantly longer than their developing country counterparts. Du Pleissis (2006) similarly finds that the developing country business cycles are not significantly shorter than those of the developed countries, when using real GDP to compare seven emerging market economies with the USA, EMU and Japan.

Finally, from Tables 2.5(a) and 2.5(b) it is interesting to note that the average length of contractionary phases is fairly equal between all the regional groups, indicating that the slow growth in developing countries is not the result of excessively long recessions.

Departing from the regional and income grouping analysis, it is also prudent to examine business cycle duration for each of the countries in the sample. Consequently, Table 2.6 provides the details of the business cycles, and also the data period, for each country within a region.

Examination of Table 2.6 reveals some noticeable outliers within each regional group; within the Asian group, there are two outliers namely Bangladesh and Hong Kong, which have significantly shorter average length business cycles than the other Asian countries. Furthermore, Hong Kong, Lithuania and Macedonia are the only countries within this sample which have an average contraction length in excess of the average expansion length, implying that they are experiencing negative economic growth in terms of industrial production. This may be explained by a move away from industrial production towards services and other components of GDP in these economies. In particular, Hong Kong has undergone massive structural transformation with a significant movement from manufacturing to services over the sampling period;

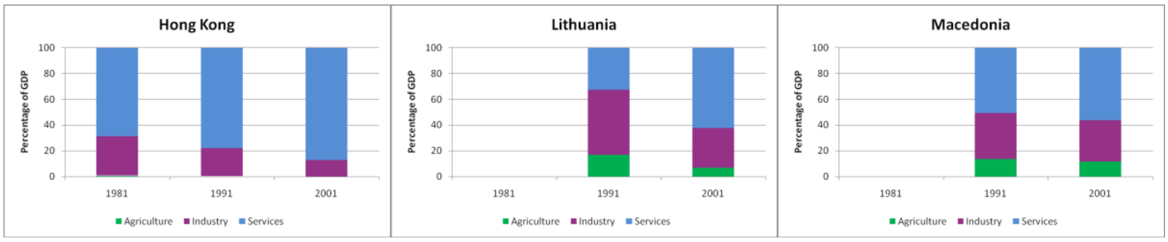
> "*During the 1960s and 1970s, an abundant supply of inexpensive labour supported the rapid growth of Hong Kong's manufacturing sector. By the late 1970s, however, Hong Kong's competitiveness in manufacturing had started to erode as land and labour costs rose. When China began its policy of economic reform in 1978, manufacturing started to relocate from Hong Kong to southern China, where labour and facility costs were much lower…The extensive transfer of manufacturing operations and the sustained rapid increase in China's export activity boosted the development of supporting service industries in Hong Kong, mot notably in trade and financial services."* (Husain, 1997, pp.3–4)

**Table 2.6** **Average Business Cycle Duration (By Country)**

| Region | Country | Period | Average Duration (in quarters) | | | |
|---|---|---|---|---|---|---|
| | | | Expansion Phases | Contraction Phases | Business Cycle | |
| | | | | | P-P | T-T |
| | US | 1960:1 – 2005:4 | 16.7 | 4.4 | 18.8 | 21.1 |
| | UK | 1960:1 – 2005:3 | 15.1 | 4.9 | 21.3 | 21.5 |
| | Japan | 1960:1 – 2005:4 | 12.7 | 5.1 | 18.0 | 17.7 |
| **Africa** | Côte d'Ivoire | 1968:1 – 2003:4 | 6.1 | 5.6 | 11.7 | 12.5 |
| | Malawi | 1970:1 – 2004:2 | 6.7 | 5.2 | 12.1 | 12.0 |
| | Nigeria | 1970:1 – 2003:4 | 8.3 | 5.9 | 14.1 | 15.2 |
| | Senegal | 1985:4 – 2003:4 | 8.0 | 4.3 | 12.3 | 12.3 |
| | South Africa | 1965:3 – 2005:1 | 12.3 | 8.4 | 21.1 | 21.1 |
| **North Africa** | Israel | 1960:3 – 2004:4 | 21.9 | 6.5 | 27.9 | 28.4 |
| | Jordan | 1972:1 – 2004:4 | 13.2 | 5.6 | 11.7 | 12.5 |
| | Morocco | 1965:3 – 2003:3 | 24.8 | 4.3 | 19.7 | 29.1 |
| | Tunisia | 1967:1 – 2005:1 | 20.3 | 4.0 | 17.5 | 30.7 |
| **Latin America** | Argentina | 1994:1 – 2004:1 | 6.0 | 6.0 | 10.5 | 12.5 |
| | Barbados | 1973:1 – 2004:4 | 10.7 | 5.9 | 15.7 | 16.5 |
| | Brazil | 1991:1 – 2005:1 | 31.1 | 3.2 | 11.2 | 11.1 |
| | Chile | 1965:3 – 2005:1 | 11.6 | 5.2 | 16.9 | 17.2 |
| | Colombia | 1980:1 – 2005:1 | 10.3 | 4.8 | 12.8 | 15.1 |
| | Mexico | 1965:3 – 2005:1 | 14.8 | 6.0 | 19.6 | 21.5 |
| | Peru | 1979:1 – 2005:1 | 8.8 | 6.0 | 15.5 | 13.6 |
| | Trinidad & Tobago | 1978:1 – 2003:4 | 8.3 | 3.9 | 12.0 | 12.0 |
| | Uruguay | 1979:1 – 2002:3 | 6.3 | 5.3 | 11.9 | 10.7 |
| **Asia** | Bangladesh | 1973:1 – 2004:3 | 7.7 | 3.3 | 11.2 | 11.1 |
| | Hong Kong | 1982:1 – 2004:4 | 6.1 | 7.7 | 12.4 | 13.9 |
| | India | 1960:3 – 2004:4 | 52.0 | 7.7 | 55.1 | 56.0 |
| | Korea, South | 1960:3 – 2005:1 | 49.1 | 3.3 | 43.1 | 52.4 |
| | Malaysia | 1970:1 – 2004:4 | 32.0 | 2.8 | 35.1 | 35.1 |
| | Pakistan | 1970:3 – 2004:3 | 23.5 | 4.4 | 28.5 | 34.0 |
| | Philippines | 1981:1 – 2005:1 | 28.0 | 5.1 | 32.5 | 32.0 |
| | Turkey | 1980:1 – 2005:1 | 13.1 | 3.5 | 16.7 | 16.7 |
| **Eastern Europe** | Hungary | 1979:1 – 2005:1 | 32.0 | 18.0 | … | 50.0 |
| | Lithuania | 1993:1 – 2005:1 | 4.5 | 6.5 | 11.1 | 15.1 |
| | Macedonia | 1993:1 – 2004:4 | 4.3 | 4.5 | 8.8 | 9.7 |
| | Romania | 1980:1 – 2005:1 | 15.3 | 9.1 | 30.0 | 24.4 |
| | Slovak Republic | 1993:1 – 2005:1 | 18.0 | 4.0 | … | 22.0 |
| | Slovenia | 1992:1 – 2005:1 | 12.4 | 4.0 | 19.1 | 12.0 |

Similarly, following the collapse of the Soviet Union and Yugoslavia, respectively, in 1991, both Lithuania and Macedonia have undergone significant structural transformations, with a movement away from industrial production towards services. Analysing the Lithuanian economy, Budrauskaite *et al*. (2002) find that, with all the markets and sources of raw material predominantly located in the Former Soviet Union, "*the output structure was designed to meet the demand of the Union, making its industries uncompetitive in the world market*" (p.74), thus necessitating the subsequent structural transformation of the economy. Examining the structure of Lithuanian GDP in 1991 and 2001, it is possible to see that the share of industrial production declined dramatically from 51% to 31%, whilst services increased from 33% to 62%. Figure 2.3 exhibits the changing composition of GDP for Hong Kong, Lithuania and Macedonia for the years 1981, 1991 and 2001.

**Figure 2.3 The Changing Composition of GDP in Hong Kong, Lithuania and Macedonia**




Of the Latin American countries, Brazil appears to be performing much better than the rest, with an average expansion phase of 31.1 quarters compared with the regional average of just 14.2 quarters. Finally, South Africa appears to be fairing slightly better than the other African countries, with an above group average business cycle length and expansion phase length, whilst Jordan appears to be fairing worse than average within the North African countries, with the shortest expansion phases and business cycle duration.

Given the focus on developing economies, an interesting comparison lies in the duration of industrial production and agricultural production cycles; Tables 2.7(a) and 2.7(b) compare the cycles in industrial production and agricultural output. As you would expect, these tables indicate that business cycles in agricultural output are on average much shorter than those in industrial output. There is also less regional difference in agricultural output cycle length.

**Table 2.7(a) Average Duration of Agricultural and Industrial Business Cycles (By Country)**

| Region | Country | Period | Average Duration (in quarters) | | | |
|---|---|---|---|---|---|---|
| | | | Expansion Phases | Contraction Phases | Business Cycle | |
| | | | | | P-P | T-T |
| | US | I | 12.5 | 3.3 | 14.1 | 15.8 |
| | | A | 5.9 | 3.8 | 9.6 | 9.7 |
| | UK | I | 11.3 | 3.7 | 16.0 | 16.1 |
| | | A | 7.0 | 3.4 | 10.4 | 11.0 |
| **Africa** | | | | | | |
| | South Africa | I | 9.2 | 6.3 | 15.8 | 15.8 |
| | | A | 4.5 | 6.5 | 7.1 | 12.8 |
| **Latin America** | | | | | | |
| | Brazil | I | 23.3 | 2.4 | 8.4 | 8.3 |
| | | A | 8.3 | 3.8 | 12.0 | 6.0 |
| | Chile | I | 8.7 | 3.9 | 12.7 | 12.9 |
| | | A | 5.6 | 6.8 | 9.0 | 5.3 |
| | Colombia | I | 7.7 | 3.6 | 9.6 | 11.3 |
| | | A | 3.0 | 4.5 | 8.0 | 6.8 |
| | Mexico | I | 11.1 | 4.5 | 14.7 | 16.1 |
| | | A | 6.7 | 3.0 | 9.7 | 9.8 |
| **Asia** | | | | | | |
| | India | I | 39.0 | 5.8 | 41.3 | 42.0 |
| | | A | 3.0 | 1.8 | 4.8 | 4.9 |
| | Korea, South | I | 36.8 | 2.5 | 32.3 | 39.3 |
| | | A | 6.4 | 3.2 | 8.6 | 9.6 |
| | Malaysia | I | 24.0 | 2.1 | 26.3 | 26.3 |
| | | A | 6.4 | 3.4 | 9.8 | 7.5 |
| | Philippines | I | 21.0 | 3.8 | 24.4 | 24.0 |
| | | A | 12.0 | 3.6 | 15.8 | 16.3 |
| | Turkey | I | 9.8 | 2.6 | 12.5 | 12.5 |
| | | A | 6.3 | 3.2 | 7.7 | 9.8 |
| **Eastern Europe** | | | | | | |
| | Hungary | I | 24.0 | 13.5 | … | 37.5 |
| | | A | 4.1 | 3.0 | 7.5 | 7.1 |
| | Lithuania | I | 3.4 | 4.9 | 8.3 | 11.3 |
| | | A | 4.1 | 4.3 | 7.8 | 8.8 |
| | Slovak Republic | I | 13.5 | 3.0 | … | 16.5 |
| | | A | 4.1 | 5.0 | 9.0 | 9.8 |

I = cycle in industrial (or manufacturing) production, A = cycle in agricultural production.

**Table 2.7(b) Average Duration of Agricultural and Industrial Business Cycles (By Region)**

| Region | Industrial Output | | | Agricultural Output | | |
|---|---|---|---|---|---|---|
| | Average Duration (in quarters) | | | Average Duration (in quarters) | | |
| | Expansion | Contraction | **Cycle** | Expansion | Contraction | **Cycle** |
| US, UK and Japan | 15.9 | 4.7 | **20.1** | 8.5 | 4.8 | **13.6** |
| Africa | 8.3 | 5.9 | **14.4** | 6.0 | 8.7 | **13.2** |
| North Africa | 20.0 | 5.1 | **22.2** | … | … | **…** |
| Latin America | 12.0 | 5.1 | **14.2** | 7.9 | 6.0 | **11.1** |
| Asia | 26.4 | 4.7 | **30.4** | 9.1 | 4.0 | **12.5** |
| Eastern Europe | 14.4 | 7.7 | **22.5** | 5.5 | 5.5 | **11.1** |

For notes, see Table 2.5.

From analysing both the agricultural output cycles[14] and the industrial output cycles an interesting example emerges, which is that of India. In the case of India, there is a substantial difference between the agricultural cycle and the result for the industrial output cycle. Of all the countries in the sample, India has both the longest average industrial output cycle, at nearly 56 quarters, and the shortest average agricultural cycle, at just less than 5 quarters.

Historically, India has relied very heavily on agricultural output and agriculture continues to account for 19.2% of GDP.[15] Thus, given the extremely short agricultural cycles, this reliance on agriculture may go someway to explaining India's low GDP per capita ranking; India was ranked at just 152nd (out of 232 countries) in 2004 and continues to be classified as a low income economy by the World Bank.[16] However, the structure of the Indian economy has undergone a significant shift during the last 50 years; for the period 1960 to 2004, agriculture, as a percentage of GDP, has declined by 55.1% whilst industrial production has increased by 44.1% and services have increased by 39.9%. Thus, the impact that the extremely short agricultural cycles have on the aggregate business cycle is declining. Mohanty, Singh and Jain (2003) find that prior to 1990 supply shocks, in the form of monsoon failures and oil price shocks, were the key sources of cyclical fluctuations in Indian output, but that since 1990 these fluctuations are increasingly influenced by the economy's internal dynamics. Furthermore, Mall (1999) finds that non-agricultural GDP is the key reference series for tracking business cycles in India. This further indicates the declining importance of agricultural output as a driving force of the Indian economy.

### *2.5.2. Amplitude*

The amplitude of the expansion and contraction phases of the business cycles is a measure of the extent that economic activity changes during the phase. Tables 2.8(a) and 2.8(b) summarise the average amplitude of expansion and contraction phases by regional and income groupings, whilst Table 2.9 details average amplitude for each country.

Tables 2.8(a) and 2.8(b) clearly demonstrate that the amplitude of both contraction and expansion phases is significantly greater in the developing countries than in the US, UK

[14] It has not been possible to similarly analyse business cycles in services, due to a lack of suitable data for the developing countries.
[15] Based on 2004 data for agriculture, value added (% of GDP) from the World Bank, World Development Indicators.
[16] See Table 2.2.

or Japan. In particular, the Asian countries, on average, experience 42% growth in output during expansion phases. When this is combined with the extremely long average expansion phases and short contraction phases, it helps explain the remarkably high growth rates that these countries have experienced in recent years. Conversely, the East European and African countries in the sample experience the largest decreases in economic activity during contraction phases, which may help explain their relatively poor economic growth performance.

**Table 2.8(a) Average Amplitude of Expansions and Contractions (By Region)**

| Region | Average Duration (In quarters) | | | Average Amplitude (%) | | Average GDP Growth Rate (%) |
|---|---|---|---|---|---|---|
| | Expansion | Contraction | Cycle | Expansion | Contraction | |
| US, UK and Japan | 15.9 | 4.7 | 20.1 | 11.9 | -2.7 | 2.6 |
| Africa | 8.3[§] | 5.9 | 14.4[§] | 16.8 | -15.1[§] | 2.2 |
| North Africa | 20.0 | 5.1 | 22.2 | 24.1 | -6.1 | 2.5 |
| Latin America | 12.0 | 5.1 | 14.2[§] | 17.8 | -13.9[§] | 2.5 |
| Asia | 26.4 | 4.7 | 30.4 | 42.0 | -13.2 | 5.0 |
| Eastern Europe | 14.4 | 7.7 | 22.5 | 17.7 | -16.1 | 1.0 |

**Table 2.8(b) Average Amplitude of Expansions and Contractions (By Income)**

| Region | Average Duration (In quarters) | | | Average Amplitude (%) | | Average GDP Growth Rate (%) |
|---|---|---|---|---|---|---|
| | Expansion | Contraction | Cycle | Expansion | Contraction | |
| High Income | 14.8 | 4.8 | 19.7 | 11.9 | -2.7 | 2.6 |
| Upper Middle Income | 16.6 | 6.0 | 20.4 | 24.7 | -12.9[§] | 2.9 |
| Lower Middle Income | 16.6 | 4.9 | 19.4 | 28.7 | -16.5 | 2.9 |
| Low Income | 16.0 | 5.2 | 21.3 | 16.7 | -11.8[§] | 3.5 |

Note that significant differences from the developed country benchmarks (the United States, United Kingdom and Japan) are denoted by *§* ($p < 0.05$) and **§** ($p < 0.01$). The average GDP Growth Rate is calculated from GDP growth (annual %), taken from the World Bank World Development Indicators, for the period 1980 to 2004.

Referring now to Table 2.9, which details average amplitude for each country, it is possible to see that Senegal experiences, on average, a 23.6% reduction in output during contractions and just a 19.4% increase during expansions; this suggests that, in industrial production at least, over the sample period Senegal has experienced negative economic growth. Furthermore, Hungary, Lithuania and Macedonia all experience greater decreases in output during contractions than increases during expansions and this is matched in the cases of Lithuania and Macedonia with extremely low GDP growth rates.

On the other hand South Korea experienced, on average, a massive 106.6% increase in industrial production during expansion phases and just a decrease of 7% during contractions. This suggests South Korea will have experienced dramatic growth in industrial production over the sample period. In fact, South Korea also has the highest average annual GDP growth rate of all the countries in this sample, at 6.7%.

**Table 2.9 Average Amplitude of Expansion and Contraction Phases (By Country)**

| Region | Country | Period | Average Amplitude (%) | | Average GDP Growth Rate (%) |
|---|---|---|---|---|---|
| | | | Expansion Phases | Contraction Phases | |
| | US | 1960:1 – 2005:4 | 6.4 | -1.9 | 3.0 |
| | UK | 1960:1 – 2005:3 | 18.5 | -0.1 | 2.4 |
| | Japan | 1960:1 – 2005:4 | 10.9 | -6.1 | 2.4 |
| **Africa** | Côte d'Ivoire | 1968:1 – 2003:4 | 14.0 | -8.9 | 0.8 |
| | Malawi | 1970:1 – 2004:2 | 19.6 | -16.2 | 2.5 |
| | Nigeria | 1970:1 – 2003:4 | 19.0 | -16.3 | 2.8 |
| | Senegal | 1985:4 – 2003:4 | 19.4 | -23.6 | 2.9 |
| | South Africa | 1965:3 – 2005:1 | 12.3 | -10.5 | 2.2 |
| **North Africa** | Israel | 1960:3 – 2004:4 | 25.3 | -5.9 | 4.2 |
| | Jordan | 1972:1 – 2004:4 | 26.3 | -11.4 | 4.7 |
| | Morocco | 1965:3 – 2003:3 | 14.9 | -4.8 | 3.6 |
| | Tunisia | 1967:1 – 2005:1 | 29.7 | -2.1 | 4.4 |
| **Latin America** | Argentina | 1994:1 – 2004:1 | 12.3 | -30.2 | 1.6 |
| | Barbados | 1973:1 – 2004:4 | 11.7 | -11.0 | 1.3 |
| | Brazil | 1991:1 – 2005:1 | 12.2 | -7.7 | 2.5 |
| | Chile | 1965:3 – 2005:1 | 18.4 | -7.1 | 5.1 |
| | Colombia | 1980:1 – 2005:1 | 17.1 | -8.2 | 3.1 |
| | Mexico | 1965:3 – 2005:1 | 18.1 | -9.2 | 2.8 |
| | Peru | 1979:1 – 2005:1 | 23.3 | -21.7 | 2.1 |
| | Trinidad & Tobago | 1978:1 – 2003:4 | 35.1 | -17.3 | 2.2 |
| | Uruguay | 1979:1 – 2002:3 | 12.0 | -12.4 | 1.5 |
| **Asia** | Bangladesh | 1973:1 – 2004:3 | 16.3 | -7.6 | 4.3 |
| | Hong Kong | 1982:1 – 2004:4 | 14.4 | -9.8 | 5.3 |
| | India | 1960:3 – 2004:4 | … | -3.8 | 5.7 |
| | Korea, South | 1960:3 – 2005:1 | 106.6 | -7.8 | 6.7 |
| | Malaysia | 1970:1 – 2004:4 | 56.9 | -10.3 | 6.3 |
| | Pakistan | 1970:3 – 2004:3 | 11.9 | -6.6 | 5.2 |
| | Philippines | 1981:1 – 2005:1 | 69.1 | -49.6 | 2.9 |
| | Turkey | 1980:1 – 2005:1 | 18.8 | -10.0 | 4.1 |
| **Eastern Europe** | Hungary | 1979:1 – 2005:1 | 17.8 | -28.4 | 1.5 |
| | Lithuania | 1993:1 – 2005:1 | 38.5 | -40.5 | 0.2 |
| | Macedonia | 1993:1 – 2004:4 | 8.6 | -9.2 | -0.4 |
| | Romania | 1980:1 – 2005:1 | 4.6 | -13.4 | 0.7 |
| | Slovak Republic | 1993:1 – 2005:1 | 27.1 | -3.0 | 1.7 |
| | Slovenia | 1992:1 – 2005:1 | 9.5 | -2.4 | 2.4 |

The average GDP growth rate is calculated from GDP growth (annual %), taken from the World Bank World Development Indicators, for the period 1980 to 2004.

## 2.6. SYNCHRONISATION OF BUSINESS CYCLES

### *2.6.1. Timing of Peaks and Troughs*

The coincidence of peaks and troughs of the developing country business cycles are examined to determine whether they are independent. Or, indeed whether they are related to those of the other developing countries or those of the developed countries. Given that a peak indicates that an economy is about to enter a recession and that a trough indicates that an economy is about to enter an expansion phase, it is possible to examine the timing of peaks and troughs to see whether there is any relationship between countries' business cycles.

Table 2.10 details the timings of business cycle peaks and troughs for each country, as calculated using the Bry-Boschan (1971) dating algorithm. When a country's business cycle reaches a peak this is recorded with a P in the table, whilst when a country's business cycle reaches a trough this is recorded with a T in the table. Between a peak (P) and a trough (T) the business cycle is in a contractionary phase. Between a trough (T) and a peak (P) the business cycles is in an expansionary phase.

Table 2.10 reveals that there is clearly some relationship between countries in terms of the timing of peak and troughs. Most of these are either within regional groups and/or in line with periods of significant regional crises, such as the Asian financial crisis. However, as noted by Rand and Tarp (2002), the more specific timing of the start of a recession appears to be determined by country-specific factors.

Examination of the regional groups provides evidence that the timing of peaks and troughs, and thus the business cycles, are fairly synchronised amongst the Latin American countries and amongst the Asian countries. However, there appears to be much less cohesion between the business cycles of the African countries. Kose *et al.* (2003) similarly find that African cycles tend to be driven by country specific shocks, and thus show little synchronisation.

The synchronous timing of peaks and troughs during periods of economic crisis corresponds to the notion of contagion; whereby, knowledge of a crisis elsewhere increases the probability of a crisis at home (Eichengreen *et al.*, 1996), thus yielding synchronous cycles. There are numerous explanations for the contagious nature of crises.[17]

[17] For a detailed discussion of crisis transmission mechanisms see Pesenti and Tille (2000).

**Table 2.10** **Coincidence of Peaks (P) and Troughs (T)**

| | 1979 | | | | 1980 | | | | 1981 | | | | 1982 | | | | 1983 | | | | 1984 | | | | 1985 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| UK | | P | | | | | | | | T | | | | | | | | | | P | | | T | | | | | |
| US | P | | | | | T | | | | P | | | | | | T | | | | | | | | | | | | |
| Japan | | | | | P | | T | | | | P | | | | T | | | | | | | | | | | P | | |
| Argentina | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Barbados | | | | | P | | | | | | | | | | | T | | | | | | | | | | | | |
| Brazil | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Colombia | | | | | | | | | | | | | | | | | | T | | | | | | | | | | |
| Chile | | | | | | | | | P | | | | | | | T | | | | | | P | | | | T | | |
| Mexico | | | | | | | | | | | P | | | | | | | | T | | | | | | | | P | |
| Peru | | | | | | | | P | | | | | | | | | | | | T | | | | | | | | |
| Trinidad | | | | | | P | | | T | | | | | P | | | | | T | | | | P | | T | | | |
| Uruguay | | | T | | | | | P | | | | | | | | T | | | | | | P | | | | T | | |
| Bangladesh | | | | | T | | | | | P | | | | | | T | | | | | | | | | | | P | |
| Hong Kong | | | | | | | | | | | | | | | T | | | | | | | | P | | | | T | |
| India | P | | | | T | | | | | | | | | | | | | | | | | | | | | | | |
| Korea, South | P | | | | | T | | | | | | | | | | | | | | | | | | | | | | |
| Malaysia | | | | | | | | | | | | | | | | | | | | | | P | | | | T | | |
| Pakistan | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Philippines | | | | | | | | | | | | | | | | | | | | | | | | P | | | | |
| Turkey | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Côte d'Ivoire | | | | | | | | | P | | | | T | | P | | | | | T | | | | | P | | | |
| Malawi | | | | | | | | T | | | P | | T | | | | | | | P | | T | | | | | | |
| Nigeria | | | | | | | | P | | | T | | | P | | | | | | | | T | | | | | | |
| Senegal | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| South Africa | | | | | | | | | | | | P | | | | | T | | | | | P | | | | | | |
| Israel | P | | | | T | | | | | P | | | | T | | | | | | | | | | | | | | |
| Jordan | T | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Morocco | | | | P | | | | T | | | | | | | P | | | | | | | | | | T | | | |
| Tunisia | | | | | | P | | | | | | | | | T | | | | | | | | | | | | | |

| | 1986 | | | | 1987 | | | | 1988 | | | | 1989 | | | | 1990 | | | | 1991 | | | | 1992 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| UK | | | | | | | | | | | | | | | | | | P | | | | | T | | | | | |
| US | | | | | | | | | | | | P | | T | | | | | P | | T | | | | | | | |
| Japan | | | T | | | | | | | | | | | | | | | | | | | P | | | | | | |
| Argentina | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Barbados | P | | | T | | | | | | | | | | | | | | | | P | | | | | | | | |
| Brazil | | | | | | | | | | | | | | | | | | | | | | | P | | | T | | |
| Colombia | | | | | | | | | P | | | | T | | | | P | | | | T | | | | | | | |
| Chile | | | | | | | | | | | | | | | | | P | | T | | | | | | | | P | |
| Mexico | | | | T | | | | | | | | | | | | | | | | | | | | | | | P | |
| Peru | | | | | | | P | | | | | | | T | | P | | | T | | | | P | | | | T | |
| Trinidad | | | | | | | | | P | | | | T | | | | | | | | | | | | | P | | |
| Uruguay | | | | | | | P | | | | | | | | T | | | | | P | | T | | | P | | | |
| Bangladesh | T | | | | P | | T | | | | | | | | | P | | | T | | | | | | | | | |
| Hong Kong | | | | | | | | | | | | P | | | | | T | | | | | | | | | P | | |
| India | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Korea, South | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Malaysia | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pakistan | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Philippines | T | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Turkey | | | | | | | | | P | | | T | | | | | | | | | | | | | | | | |
| Côte d'Ivoire | T | | | | | | P | | | | | | | T | | P | | | | | | | | | | | T | |
| Malawi | | P | | | | T | | | | | | | | | | | | | | | | | | P | | | | |
| Nigeria | P | | | T | | | | | | | | | | | | | | | | P | | | | | | | | |
| Senegal | | | | | | | | T | | | | | | | | | | | | P | | T | | | | | | P |
| South Africa | | T | | | | | | | | | | | | P | | | | | | | | | | | | | T | |
| Israel | | | | | P | | | | | | | | | T | | | | | | | | | | | | | | |
| Jordan | P | | | T | | | | P | | | T | | | | | | | P | | | T | | | P | | | T | |
| Morocco | | | | | | | | | | | | | | | | | | | | | | | | | P | | | |
| Tunisia | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

**Table 2.10** **Coincidence of Peaks (P) and Troughs (T) (continued…)**

| | 1993 | | | | 1994 | | | | 1995 | | | | 1996 | | | | 1997 | | | | 1998 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| UK | | | | | | | | | | | | | | | | | | | | | | | | |
| US | | | | | | | | | | | | | | | | | | | | | | | | |
| Japan | | | | T | | | | | | | | | | | | | | P | | | | | T | |
| Argentina | | | | | | | P | | | | | T | | | | | | | | | P | | | |
| Barbados | | T | | | | | | | | | P | | | T | | | | | | | | | | P |
| Brazil | | | | | | | | | P | | T | | | | | | | | P | | | | | |
| Colombia | | | | | | | | | | | | P | | | | T | | | | | P | | | |
| Chile | | T | | | | | | | | | | | | | | | | | | P | | | | |
| Mexico | | | T | | | P | | | | T | | | | | | | | | | | | | | |
| Peru | | | | | | | | | | | | | | | | | | P | | | | | | |
| Trinidad | | | T | | | | | | | | | | | | | | | | | | | | | |
| Uruguay | | T | | | | P | | | | | T | | | | | | | | | | | | P | |
| Bangladesh | | | | | | | | | | | | | | | | | | | | | | | | |
| Hong Kong | | | | | | T | | | P | | | | | | | | | T | | P | | | | |
| India | | | | | | | | | | | | | | | | | | | | | | | | |
| Korea, South | | | | | | | | | | | | | | | | | | | P | | | T | | |
| Malaysia | | | | | | | | | | | | | | | | | | | | P | | | T | |
| Pakistan | | | | | P | | T | | | P | | | | | | | | T | | | | | | |
| Philippines | | | | | | | | | | | | | | | | | | | | P | | | | T |
| Turkey | | | | P | | T | | | | | | | | | | | | | | | P | | | |
| Côte d'Ivoire | | | | | | | P | | T | | | | | | | | | | | | | | | |
| Malawi | | T | | P | | | | T | | | | | | | P | | | | T | | P | | | |
| Nigeria | | | | | | | | T | | | | | | | | | | | | | P | | | |
| Senegal | | | T | | | | | | P | | | | T | | | | | | | | | | | |
| South Africa | | | | | | | | | | | | | | | | | | P | | | | | | |
| Israel | | | | | | | | | | | | | | | | | | | | | | P | | |
| Jordan | | | | | | | | | | | | P | | | T | | | | | | | | | |
| Morocco | | T | | | | | P | | T | | | | | | | | | | | | | | | |
| Tunisia | | | | | T | | | | | | | | | | | | | | | | | | | |

| | 1999 | | | | 2000 | | | | 2001 | | | | 2002 | | | | 2003 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| UK | | | | | | | | P | | | | | | | | | | T | | |
| US | | | | | | P | | | | | | T | | P | | | | T | | |
| Japan | | | | | | | | P | | | | T | | | | | | | | |
| Argentina | T | | | P | | | | | | | | | T | | | | | | | |
| Barbados | | | | | | | | | | T | | | P | | T | | | | P | |
| Brazil | T | | | | | | | | P | | | T | | | | P | | T | | |
| Colombia | | | | T | | | | P | | | | | T | | | | | | | |
| Chile | T | | | | | | | | | | | P | | | | | | | | |
| Mexico | | | | | | | P | | | | | | | | | | | | T | |
| Peru | T | | | | P | | | T | | | | | | | | | | | | |
| Trinidad | | | | | | | | | | | | | | | | | | | | |
| Uruguay | | | | | | | | | | | | | | | | | | | | |
| Bangladesh | | | | | | | | | | | | | | | | | | | | |
| Hong Kong | | | T | | P | | | | | | | | | | | | | T | | |
| India | | | | | | | | | | | | | | | | | | | | |
| Korea, South | | | | | | | P | | T | | | | | | | | | | | |
| Malaysia | | | | | | | | P | | T | | | | | | | | | | |
| Pakistan | | | | P | | | | | | | | | | | | | | | | |
| Philippines | | | | | | | | | P | | | | T | | | | | | | |
| Turkey | | | T | | | | P | | | T | | | | | | | | | | |
| Côte d'Ivoire | | P | | | | | | T | | | P | | | | | | | | | |
| Malawi | | | | | | | | | | | | | T | | P | | | T | | |
| Nigeria | | | | T | | | | P | | | | T | | | | P | | | | |
| Senegal | P | | | | | | | | T | | | | | | | | P | | | |
| South Africa | | T | | | | | | | | | | | | P | | | | | | T |
| Israel | T | | | | | | P | | | | | | | | | | | | T | |
| Jordan | | | | | | | | | | | | | | | P | | T | | | |
| Morocco | | | | | | | | | | | | | | | | | | | | |
| Tunisia | | | | | | | | | | | | | P | | | | T | | | |

The Eastern European countries are excluded from this table because the sample periods for four of the six countries (Lithuania, Macedonia, Slovak Republic and Slovenia) only extend for the period 1993:1 to 2005)

Firstly, the crisis may result from a common shock, such as an oil price shock, which similarly affects several countries. Masson (1998) defines the transmission of such shocks to be *monsoonal effects*, rather than contagion. Secondly, the crisis may be transmitted through trade and financial linkages; this is the fundamentals-based contagion mechanism (Calvo and Reinhart, 1996). As with the common shock mechanism, Masson (1998) does not classify this type of transmission as contagion, but rather defines it as a *spillover effect*. Finally, the crisis may be transmitted through changes in expectations, and is predominantly associated with financial market information frictions (Pesenti and Tille, 2000). This final transmission mechanism provides an avenue for the transmission of crises to countries which are apparently unrelated, and thus is consistent with the definition of *pure* (Masson, 1998) or *true* (Calvo and Reinhart, 1996) contagion.

In light of this, several crisis episodes are considered in turn to examine the timing of recessions across the regions and the possible causes of any observed contagion. Firstly, the international oil crisis, which occurred during the period 1979 to 1980, and the subsequent recession in the industrialised countries during the early 1980s. Table 2.10 reveals that the UK, US, India, South Korea and Israel all begin a contractionary phase during 1979:1 (1979:2 for the UK), closely followed by the Latin American countries in 1980. This also corresponds with the Latin American debt crisis of the 1980s. A further lag sees the majority of the African countries experiencing a recession beginning in 1981.

The synchronisation of the business cycles at this point in time would appear to be a monsoonal effect, since the driving force is a common oil price shock. However, the developing countries appear to respond to the crisis with a lag. This could be explained by the developing countries responding to the depression in the industrialised countries rather than to the shock directly. Frankel and Roubini (2001), for example, intuitively explain that the recession amongst industrialised countries during the early 1980s depressed prices and volumes for exports from developing countries; thereby causing the developing countries themselves to enter a contractionary period and precipitating the subsequent international debt crisis. Thus, this is a fundamentals-based contagion. Following this period of recession, there is a coincidence of peaks in Latin America and Asia (plus South Africa and Jordan) during 1984 suggesting a further contractionary phase in these regions.

Secondly, the Mexican peso crisis, which began in Mexico in 1994. This crisis resulted in significant speculative pressure on the currencies of several Latin American and Asian economies (Calvo and Reinhart, 1996).[18] However, this crisis appears to have had a limited impact on the business cycles of the Latin American and Asian economies; Table 2.10 reveals that only Argentina, Brazil and Hong Kong follow Mexico into a recession. Walker (1998) suggests a number of explanations for the relatively limited extent of the Mexican crisis, in comparison to the Asian financial crisis; the Asian financial crisis occurred in 1997 and will be discussed subsequently. Firstly, potential liquidity problems were reduced as a result of Mexico's relationship with the US; "*commitment to NAFTA made the United States effectively a lender of last resort to Mexico*" (Walker, 1998, p.10). Secondly, the low ratio of domestic credit to GDP amongst the Latin American countries provided room for the central banks to raise interest rates without generating a outbreak of defaults. Thirdly, the firm stance and decisive action taken by the Latin American countries, particularly in Mexico and Argentina, acted to enhanced market credibility. Finally, Walker (1998) suggests that capital controls in Brazil and Chile may have slowed speculative flows; although no evidence is provided to support this postulation.

Finally, the Asian financial crisis, which began in July 1997 in Thailand and subsequently spilled over to Latin American countries. Looking at Table 2.10 there is a clear pattern of peaks starting in the second quarter of 1997, with the majority of countries in the sample entering recession by the end of 1998. There does not appear to be a lag between the start of recessions in the Asian countries and the start in the Latin American countries. However the Asian economies do appear to recover more quickly with Japan, South Korea, Malaysia and the Philippines all beginning expansionary phases during the later part of 1998. Interestingly, the UK and the US do not appear to be affected by the Asian financial crisis.

Kaminsky and Reinhart (2000) find that capital flows played a central role in the Asian financial crisis, and thus suggest that the financial interdependence of countries was particularly important in propagating the crisis. Where countries rely on common lenders, the behaviour of these banks can act to both exacerbate the original crisis and spread the crisis to the other borrowers. For example, following the intuition of Pesenti and Tille (2000), assume there are three countries A, B and C, and a foreign bank D. Country A experiences a currency crisis which affects the ability of domestic residents to repay loans to D. In light of this, D will try to rebuild its capital by recalling some of the loans made to borrowers in countries B and C. These borrowers now face a credit crunch, and the crisis is spread. However, the impact of this crisis on countries B and C relies on the dependence on bank D; the greater the initial dependence on bank D, the greater the

[18] Notably, Brazil and Argentina in Latin America, and Hong Kong, Malaysia, the Philippines and Thailand in Asia.

impact of the crisis. Thus, providing an explanation as to why the contagion affects some countries more than others. In the case of the Asian financial crisis, Japanese banks were important lenders to the Asian economies. In particular, on the eve of the crisis, 54% of Thai liabilities were held by Japanese banks (Kaminsky and Reinhart, 2000). Thus, assuming that the Japanese banks tried to recoup their losses by recalling capital from the other Asian economies, this provides a promising explanation. In particular, if the Japanese banks held few US and UK liabilities, then this helps to explain why the US and UK avoided the onset of a contractionary phase.

Another possible explanation for both the pattern of contagion during the Asian Financial Crisis and the reason for US and UK escaping unscathed, arises from the work of Corsetti *et al*. (1999). They examine the mechanism of international transmission of exchange rate shocks and demonstrate how trade linkages may result in the contagion of such shocks. Following the intuition of Corsetti *et al*. (1999), let there be three countries A, B and C, of which A and B are trading partners; if country A devalues its currency then country B becomes less competitive and consequently will also devalue. Thus, the shock is passed on to country B and the movements of the two business cycles will be synchronised. On the other hand, if country B is large relative to A but both A and B are small relative to C, then Corsetti *et al*. (1999) demonstrate that country B is better off not matching the devaluation. Consequently, in this case there will be no contagion effect and the business cycles of countries A and B will not be synchronised. The US and the UK are important trading partners for many of the countries affected by the Asian Financial Crisis. However the US and UK are also relatively large compared to these countries. If C is considered to be the rest of the world then, certainly in the case of the UK, the second case holds, whereby the US and UK are better off not matching the devaluations of the countries affected by the crisis; thus there is no contagion to the US or UK.

However, whilst these interpretations successfully explain why the US and UK were unaffected by the Asian financial crisis, they are not satisfactory in explaining the pattern of contagion amongst the developing countries. Given the number of countries involved and their geographic spread, it is highly unlikely that the contagion is entirely the result of similarities in macroeconomic fundamentals. Thus, another explanation is required.

Calvo (1999), Calvo and Mendoza (2000) and Mendoza and Smith (2002), amongst others, relate the observed pattern of contagion to asymmetrical information in financial markets. One of the key assumptions underlying these papers is that country-specific information is costly. For example, Calvo (1999) and Calvo and Mendoza (2000) assume that gathering country specific information involves large fixed costs. Thus, two types of investors will exist: the informed and the uniformed. Informed investors are much more likely to leverage their portfolios, and as such these investors will be subject to marginal calls.[19] Meanwhile, uniformed investors simply mimic the behaviour of the informed investors. Consequently, if the uninformed investor observes that the informed investor is selling securities they will follow suit, resulting in a generalised outflow of capital from the economy. However, the decision of the informed individual reflects information relevant to them, such as a marginal call, and not necessarily information about the condition of the economy. Thus, the reaction of the uninformed may cause a crisis which has nothing to do with the fundamentals of the economy. Furthermore, since gathering information is costly, there will be a tendency for investors to consider groups of countries within regions to be the same. As such, country-specific information will be applied to the entire group. Thus, the reaction of the uninformed provides a mechanism by which the whole region can catch the contagion, with no change in macroeconomic fundamentals. However, whilst this explains the pattern of contagion within regional groups, it fails to explain the contagion between the Asian economies and the Latin American economies.

Thus, this approach is enhanced by Kodres and Pritsker (2002), who place emphasis on contagion through *cross-market rebalancing*, to explain the observed patterns of contagion during the Asian financial crisis. Cross-market rebalancing occurs as a result of investors, who are active in more than one market, optimally adjusting their portfolios. Assume that there is a negative shock in one country; Thailand, in the case of the Asian financial crisis. In response to this shock, investors will optimally adjust their portfolios in other markets. In this way, contagion is generated as the shock is transmitted to the other markets, without necessitating that the countries are linked through macroeconomic fundamentals. Thus, this helps to explain the contagion between the weakly linked Asian and Latin American economies. This effect is further magnified in markets with information asymmetries. Therefore, given that information asymmetries are greatest amongst the developing countries, this can also explain why the developing economies suffered the worst of the contagion during the Asian financial crisis, whilst the US and UK escaped relatively unscathed.

[19] Marginal calls occur when, for example, securities purchased with borrowed money decrease in value and thus the investor will be required to increase the margin deposited or close out the position.

### *2.6.2. Concordance*

The previous analysis has highlighted the contagion of crises amongst countries, and the consequent synchronisation of business cycle peaks and troughs. However, this analysis is now extended to examine the overall degree of synchronisation between the business cycles. This is performed through the use of the Harding and Pagan (2002) concordance statistic, which measures the degree of synchronisation between the business cycles of two countries. Theoretically, it is expected that the developing country business cycles will be synchronised with the business cycles of their major trading partners and investors, as discussed in Aruoba (2001). For example, a significant positive concordance statistic is to be expected between a developing country's business cycle and the cycles of the key recipients of its exports. If the purchasing country goes into a recession, their import demand will decrease and hence the developing country's exports will decline stimulating the onset of a recession. Table 2.11 details the key trading partners for each of the countries included in this analysis. Thus, from the details provided in Table 2.11, a strong degree of synchronisation between the majority of developing country cycles and the US business cycle should be expected. Although, this is not the case for the Eastern European region; on average, trade with the US comprises just 3% of exports and 2.6% of imports.[20]

However, Caldéron *et al.* (2007) find that whilst trade intensity is an important factor in increasing business cycle synchronisation amongst the industrialised countries, this is of significantly less importance in the synchronisation between developed and developing country cycles and between developing country cycles. This is also consistent with previous research which suggests that whilst there is a strong degree of synchronisation between industrialised country business cycles,[21] the degree of synchronisation for developing country cycles is rather more varied. For example, Kose *et al.* (2003) suggest that developing country business cycle fluctuations tend to be country specific, particularly in Asia and Africa, and consequently exhibit little synchronisation with other business cycles.

[20] Averages calculated from annual volume of trade data for exports and imports (cif) from the IMF Direction of Trade Statistics (DOTS) for the period 1985 to 2005.

[21] For example, Backus, Kehoe and Kydland (1995) find strong positive correlations between US output and nine other industrialised country business cycles.

**Table 2.11** **Key Trading Partners for Sample Countries**

| | | Exports – Key Trading Partners | | | Imports – Key Trading Partners | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 1 | 2 | 3 |
| **United States** | **1985** | **Canada** | Japan | Mexico | **Japan** | **Canada** | Germany |
| | **1995** | **Canada** | Japan | Mexico | **Canada** | Japan | Mexico |
| | **2005** | **Canada** | Mexico | Japan | Canada | China | Mexico |
| **United Kingdom** | **1985** | US | Germany | France | Germany | US | France |
| | **1995** | US | Germany | France | Germany | US | France |
| | **2005** | US | Germany | France | Germany | US | France |
| **Japan** | **1985** | **US** | China | Korea, South | **US** | Saudi Arabia | Indonesia |
| | **1995** | **US** | Korea, South | Hong Kong | **US** | China | Korea, South |
| | **2005** | **US** | China | Korea, South | **China** | US | Saudi Arabia |
| **Africa** | | | | | | | |
| **Côte d'Ivoire** | **1985** | Netherlands | France | US | **France** | Nigeria | US |
| | **1995** | **France** | Netherlands | Italy | **France** | Nigeria | US |
| | **2005** | France | US | Netherlands | **France** | **Nigeria** | Singapore |
| **Malawi** | **1985** | **UK** | US | Germany | **South Africa** | UK | Japan |
| | **1995** | Germany | US | France | **South Africa** | UK | Germany |
| | **2005** | US | South Africa | Egypt | **South Africa** | Zambia | Mozambique |
| **Nigeria** | **1985** | US | Italy | France | **UK** | US | Germany |
| | **1995** | **US** | Spain | France | UK | US | Germany |
| | **2005** | **US** | Spain | Brazil | China | US | UK |
| **Senegal** | **1985** | **France** | Mali | Côte d'Ivoire | **France** | US | Côte d'Ivoire |
| | **1995** | **India** | France | Italy | **France** | Nigeria | US |
| | **2005** | Mali | India | France | **France** | Nigeria | *Brazil* |
| **South Africa** | **1985** | … | … | … | … | … | … |
| | **1995** | … | … | … | … | … | … |
| | **2005** | Japan | UK | US | Germany | China | US |
| **North Africa** | | | | | | | |
| **Israel** | **1985** | **US** | UK | Germany | **US** | Germany | UK |
| | **1995** | **US** | Japan | UK | **US** | Germany | UK |
| | **2005** | **US** | Belgium | Hong Kong | US | Belgium | Germany |
| **Jordan** | **1985** | **Iraq** | **India** | Saudi Arabia | Saudi Arabia | US | Iraq |
| | **1995** | **Iraq** | India | Saudi Arabia | Iraq | US | Germany |
| | **2005** | **US** | Iraq | India | **Saudi Arabia** | China | Germany |
| **Tunisia** | **1985** | **France** | Italy | Germany | **France** | Italy | Germany |
| | **1995** | **France** | **Italy** | Germany | **France** | Italy | Germany |
| | **2005** | **France** | **Italy** | Germany | **France** | **Italy** | Germany |
| **Latin America** | | | | | | | |
| **Argentina** | **1985** | US | Netherlands | Brazil | US | Brazil | Germany |
| | **1995** | **Brazil** | US | Chile | **Brazil** | **US** | Italy |
| | **2005** | Brazil | US | Chile | **Brazil** | US | China |
| **Barbados** | **1985** | **US** | Guyana | UK | **US** | T&T | UK |
| | **1995** | UK | US | T&T | **US** | T&T | UK |
| | **2005** | US | T&T | UK | **US** | **T&T** | UK |
| **Brazil** | **1985** | **US** | Netherlands | Japan | **US** | Iraq | Nigeria |
| | **1995** | **US** | Argentina | Japan | **US** | Argentina | Germany |
| | **2005** | **US** | Argentina | China | US | Argentina | Germany |
| **Chile** | **1985** | **US** | Japan | Germany | **US** | Venezuela | Brazil |
| | **1995** | Japan | US | UK | **US** | Argentina | Brazil |
| | **2005** | US | Japan | China | Argentina | US | Brazil |
| **Colombia** | **1985** | **US** | Germany | Netherlands | **US** | Japan | Germany |
| | **1995** | **US** | Venezuela | Germany | **US** | Venezuela | Japan |
| | **2005** | **US** | Venezuela | Ecuador | **US** | Mexico | China |
| **Mexico** | **1985** | **US** | Japan | Spain | **US** | Japan | *Germany* |
| | **1995** | **US** | *Canada* | *Japan* | **US** | Japan | *Germany* |
| | **2005** | **US** | *Canada* | *Japan* | **US** | China | Japan |
| **Peru** | **1985** | **US** | Japan | Germany | **US** | Argentina | Japan |
| | **1995** | US | Japan | UK | **US** | Colombia | Chile |
| | **2005** | **US** | China | Chile | US | China | Brazil |
| **Trinidad & Tobago** | **1985** | **US** | *Italy* | *UK* | **US** | Japan | UK |
| | **1995** | **US** | Jamaica | France | **US** | UK | Venezuela |
| | **2005** | **US** | Jamaica | *Barbados* | **US** | Brazil | Japan |
| **Uruguay** | **1985** | Brazil | US | Germany | Brazil | Iran | Argentina |
| | **1995** | **Brazil** | Argentina | US | **Brazil** | **Argentina** | US |
| | **2005** | **US** | Brazil | Argentina | **Brazil** | **Argentina** | Russia |

**Table 2.11 Key Trading Partners for Sample Countries (continued…)**

| | | Exports – Key Trading Partners | | | Imports – Key Trading Partners | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 1 | 2 | 3 |
| **Asia** | | | | | | | |
| **Bangladesh** | **1985** | US | Iran | Japan | Japan | US | Singapore |
| | **1995** | **US** | UK | Germany | India | China | Japan |
| | **2005** | **US** | Germany | UK | India | China | Kuwait |
| **Hong Kong** | **1985** | **US** | **China** | *Japan* | **China** | **Japan** | US |
| | **1995** | **China** | **US** | Japan | **China** | Japan | US |
| | **2005** | **China** | US | *Japan* | **China** | Japan | Singapore |
| **India** | **1985** | **US** | Japan | UK | US | Japan | Germany |
| | **1995** | US | Japan | UK | US | Germany | Japan |
| | **2005** | US | UAE | China | China | US | Switzerland |
| **Korea, South** | **1985** | **US** | Japan | Hong Kong | **Japan** | **US** | *Malaysia* |
| | **1995** | **US** | Japan | Hong Kong | **Japan** | **US** | China |
| | **2005** | **China** | US | Japan | Japan | China | US |
| **Malaysia** | **1985** | **Japan** | **Singapore** | US | **Japan** | Singapore | US |
| | **1995** | **US** | **Singapore** | Japan | **Japan** | US | Singapore |
| | **2005** | US | Singapore | Japan | Japan | US | Singapore |
| **Pakistan** | **1985** | Japan | US | Saudi Arabia | US | Japan | Saudi Arabia |
| | **1995** | US | Hong Kong | Germany | Japan | US | Malaysia |
| | **2005** | **US** | UAE | Afghanistan | Saudi Arabia | UAE | China |
| **Philippines** | **1985** | **US** | Japan | Singapore | **US** | Japan | Malaysia |
| | **1995** | **US** | Japan | Singapore | **Japan** | **US** | Saudi Arabia |
| | **2005** | US | Japan | Singapore | **US** | Japan | Singapore |
| **Turkey** | **1985** | Germany | Iran | Iraq | Germany | Iran | Iraq |
| | **1995** | **Germany** | US | Italy | Germany | US | Italy |
| | **2005** | Germany | UK | Italy | Germany | Russia | Italy |
| **Eastern Europe** | | | | | | | |
| **Hungary** | **1985** | **Germany** | Austria | Poland | **Germany** | Austria | Poland |
| | **1995** | **Germany** | Austria | Italy | **Germany** | Russia | Austria |
| | **2005** | **Germany** | Italy | Austria | **Germany** | Russia | China |
| **Lithuania** | **1985** | … | … | … | … | … | … |
| | **1995** | **Russia** | Germany | Belarus | **Russia** | Germany | *Poland* |
| | **2005** | Russia | Latvia | Germany | **Russia** | Germany | Poland |
| **Macedonia** | **1985** | … | … | … | … | … | … |
| | **1995** | **Bulgaria** | Germany | Italy | Germany | Bulgaria | Italy |
| | **2005** | **S&M** | Germany | Greece | Russia | Germany | Greece |
| **Romania** | **1985** | Germany | Italy | US | Egypt | Germany | Iran |
| | **1995** | Germany | Italy | France | Germany | Italy | Russia |
| | **2005** | Germany | Italy | France | Italy | Germany | Russia |
| **Slovak Republic** | **1985** | | | | | | |
| | **1995** | **Czech Republic** | Germany | *Austria* | **Czech Republic** | Russia | Germany |
| | **2005** | **Germany** | Czech Republic | Austria | **Germany** | Czech Republic | Russia |
| **Slovenia** | **1985** | | | | | | |
| | **1995** | **Germany** | Italy | Croatia | **Germany** | Italy | Austria |
| | **2005** | Germany | Italy | Croatia | Germany | Italy | Austria |

S&M – Serbia and Montenegro, T&T – Trinidad and Tobago, UAE – United Arab Emirates.

Note that trading partners marked in **bold** indicates that trade exceeds 20%, whilst *italicised* trading partners indicate that trade is less than 5%. The key trading partners are calculated from annual volume of trade data for exports and imports (cif) from the IMF Direction of Trade Statistics (DOTS).

Table 2.12 details concordance statistics and pair-wise correlations for all the countries; the concordance statistic is above the diagonal and the correlation coefficient below. As anticipated, there is strong significant concordance between the US and UK business cycles. However, neither of these cycles are significantly concordant with the Japanese business cycle. The results for the synchronisation of the developing country business cycles are also somewhat varied, as expected.

Firstly, the synchronisation between the developed and the developing country business cycles is examined. From Table 2.12, it is evident that there is significant concordance between the US and Bangladesh, Hong Kong, India, Israel, South Korea, Mexico and Uruguay, whilst there is significant concordance between Japan and Brazil, the Philippines and Romania. None of the countries are significantly concordant with the UK business cycle, although the positive correlations between the UK and India and Israel are significant. In most cases where there is a strong degree of synchronisation between the developed and developing country business cycles, the developed country is one of the key procurers of the developing country's exports; for example, throughout the sample period the US was the main procurer of Israel's exports.

Secondly, the synchronisation between developing country business cycles within regional groups is examined. Within Latin America, the only significant concordance statistic is between Brazil and Peru, although there are several significant positive correlations between the Latin American cycles. Within the Asian countries, there is significant concordance between India and Bangladesh, between India and South Korea and between the Philippines and Malaysia. From the previous turning point analysis, this lack of synchronisation between the Asian economies is surprising, especially as the sampling period covers the Asian Financial Crisis. However, it is consistent with the finding of Kose *et al.* (2003) that business cycle fluctuations in Asia tend to be country specific. There are no significant concordances between the North African countries; however Nigeria and Malawi are significantly concordant. Finally, within the Eastern European countries there is significant concordance between Romania and the Slovak Republic, between Romania and Slovenia, and between the Slovak Republic and Slovenia.

**Table 2.12** **Concordance and Correlation Statistics**

| | US | UK | JP | AG | BB | BR | CB | CL | MX | PE | TT | UG | BS | HK | IN | KO | MY | PK | PH | TK | IV | MI | NG | SG | SA | IS | JO | MC | HN | LT | MK | RM | SX | SJ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| US | . | 0.77** | 0.63 | 0.58 | 0.61 | 0.68 | 0.70 | 0.66 | 0.70* | 0.61 | 0.62 | 0.61* | 0.77* | 0.58* | 0.79* | 0.79* | 0.70 | 0.69 | 0.68 | 0.67 | 0.57 | 0.58 | 0.5 | 0.62 | 0.55 | 0.81** | 0.65 | 0.6 | 0.67 | 0.34** | 0.43 | 0.56 | 0.61 | 0.52 |
| UK | 0.39** | . | 0.58 | 0.53 | 0.58 | 0.66 | 0.67 | 0.63 | 0.61 | 0.45 | 0.61 | 0.50 | 0.64 | 0.49 | 0.76 | 0.74 | 0.71 | 0.68 | 0.69 | 0.64 | 0.52 | 0.57 | 0.55 | 0.57 | 0.54 | 0.68 | 0.66 | 0.67 | 0.66 | 0.34** | 0.43 | 0.58 | 0.61 | 0.52 |
| JP | 0.08 | -0.04 | . | 0.61 | 0.66 | 0.70* | 0.55 | 0.61 | 0.69 | 0.59 | 0.65 | 0.40 | 0.64 | 0.49 | 0.66 | 0.70 | 0.71 | 0.52 | 0.75* | 0.64 | 0.44 | 0.57 | 0.63 | 0.51 | 0.64 | 0.54 | 0.62 | 0.63 | 0.56 | 0.45 | 0.55 | 0.67 | 0.77 | 0.71 |
| AG | 0.15 | 0.03 | 0.22 | . | 0.53 | 0.66 | 0.58 | 0.45 | 0.58 | 0.63 | 0.53 | 0.63 | 0.53 | 0.55 | 0.53 | 0.55 | 0.61 | 0.45 | 0.68 | 0.66 | 0.50 | 0.61 | 0.55 | 0.55 | 0.37 | 0.61 | 0.39 | 0.58 | 0.53 | 0.50 | 0.71* | 0.58 | 0.63 | 0.66 |
| BB | 0.14 | 0.07 | 0.27** | 0.04 | . | 0.40 | 0.57 | 0.59 | 0.59 | 0.55 | 0.59 | 0.60 | 0.54 | 0.53 | 0.56 | 0.56 | 0.55 | 0.58 | 0.49 | 0.58 | 0.54 | 0.57 | 0.65 | 0.74** | 0.52 | 0.48 | 0.6 | 0.57 | 0.50 | 0.57 | 0.39 | 0.73** | 0.57 | 0.65 |
| BR | 0.19 | 0.15 | 0.35* | 0.32* | -0.23 | . | 0.64 | 0.64 | 0.52 | 0.76* | 0.58 | 0.46 | 0.68 | 0.42 | 0.68 | 0.70 | 0.74 | 0.40 | 0.80** | 0.66 | 0.48 | 0.46 | 0.58 | 0.44 | 0.74** | 0.70 | 0.64 | 0.58 | 0.72 | 0.45 | 0.45 | 0.62 | 0.73 | 0.71 |
| CB | 0.20 | 0.16 | -0.07 | 0.15 | 0.01 | 0.17 | . | 0.60 | 0.52 | 0.64 | 0.66 | 0.52 | 0.66 | 0.53 | 0.70 | 0.69 | 0.69 | 0.60 | 0.71 | 0.80** | 0.51 | 0.54 | 0.54 | 0.39 | 0.49 | 0.70 | 0.69 | 0.54 | 0.67 | 0.61 | 0.52 | 0.64 | 0.66 | 0.60 |
| CL | 0.14 | 0.07 | 0.06 | -0.13 | 0.11 | 0.17 | 0.02 | . | 0.68 | 0.6 | 0.66 | 0.63 | 0.69 | 0.56 | 0.67 | 0.65 | 0.76* | 0.61 | 0.72 | 0.65 | 0.55 | 0.48 | 0.56 | 0.55 | 0.73* | 0.67 | 0.59 | 0.64 | 0.53 | 0.41 | 0.45 | 0.59 | 0.77 | 0.69 |
| MX | 0.28** | 0.07 | 0.28** | 0.15 | 0.12 | -0.04 | -0.12 | 0.25* | . | 0.45 | 0.66 | 0.59 | 0.63 | 0.46 | 0.63 | 0.61 | 0.62 | 0.67 | 0.66 | 0.59 | 0.57 | 0.54 | 0.64 | 0.62 | 0.53 | 0.65 | 0.59 | 0.64 | 0.45 | 0.36* | 0.59 | 0.47 | 0.55 | 0.44 |
| PE | 0.12 | -0.27** | 0.1 | 0.27** | 0.06 | 0.43** | 0.16 | 0.13 | -0.17 | . | 0.66 | 0.52 | 0.67 | 0.44 | 0.61 | 0.65 | 0.58 | 0.40 | 0.56 | 0.63 | 0.66 | 0.44 | 0.49 | 0.30 | 0.59 | 0.63 | 0.58 | 0.57 | 0.68 | 0.43 | 0.43 | 0.71* | 0.80 | 0.75 |
| TT | -0.10 | -0.11 | 0.07 | ... | 0.07 | -0.23* | 0.08 | 0.08 | 0.15 | 0.23* | . | 0.51 | 0.67 | 0.44 | 0.77* | 0.71 | 0.76 | 0.55 | 0.70 | 0.73 | 0.51 | 0.44 | 0.58 | 0.63 | 0.53 | 0.57 | 0.69 | 0.84** | 0.67 | 0.64 | 0.45 | 0.64 | 0.91** | 0.79* |
| UG | 0.33** | 0.07 | -0.17 | 0.30** | 0.23* | 0.01 | 0.08 | 0.34** | 0.24* | 0.07 | 0.12 | . | 0.44 | 0.61* | 0.44 | 0.42 | 0.47 | 0.54 | 0.45 | 0.50 | 0.64* | 0.53 | 0.53 | 0.60 | 0.48 | 0.66** | 0.44 | 0.45 | 0.48 | 0.39 | 0.52 | 0.49 | 0.39 | 0.46 |
| BS | 0.33** | -0.04 | 0.03 | ... | -0.06 | ... | -0.01 | 0.16 | 0.06 | 0.25* | -0.09 | -0.06 | . | 0.43 | 0.86** | 0.8 | 0.73 | 0.56 | 0.73 | 0.68 | 0.52 | 0.49 | 0.43 | 0.63 | 0.60 | 0.70 | 0.68 | 0.65 | 0.74 | 0.57 | 0.39 | 0.58 | 0.84 | 0.73 |
| HK | 0.32** | 0.10 | 0.08 | 0.16 | 0.11 | 0.02 | 0.11 | 0.24* | -0.01 | -0.09 | 0.02 | 0.20* | 0.00 | . | 0.43 | 0.47 | 0.46 | 0.57 | 0.48 | 0.47 | 0.33* | 0.62* | 0.42 | 0.46 | 0.41 | 0.55 | 0.35 | 0.38 | 0.35 | 0.55 | 0.64 | 0.51 | 0.36* | 0.42 |
| IN | 0.35** | 0.23* | -0.13 | ... | -0.17 | ... | ... | -0.13 | -0.14 | ... | -0.10 | -0.02 | 0.44** | 0.16 | . | 0.94** | 0.87 | 0.70 | 0.83 | 0.82 | 0.48 | 0.55 | 0.51 | 0.68 | 0.56 | 0.72 | 0.78 | 0.77 | 0.80 | 0.57 | 0.39 | 0.61 | 0.84 | 0.73 |
| KO | 0.35** | 0.18 | 0.15 | 0.10 | -0.07 | 0.20* | 0.05 | -0.07 | -0.09 | 0.20* | -0.16 | -0.11 | 0.19 | 0.20* | 0.61** | . | 0.87 | 0.68 | 0.81 | 0.82 | 0.44 | 0.57 | 0.49 | 0.66 | 0.56 | 0.70 | 0.72 | 0.73 | 0.74 | 0.45 | 0.41 | 0.64 | 0.77 | 0.67 |
| MY | -0.02 | 0.05 | 0.18 | 0.25* | -0.11 | 0.34** | 0.11 | 0.34** | -0.07 | -0.04 | 0.03 | 0.07 | -0.15 | 0.18 | -0.06 | 0.24* | . | 0.69 | 0.90** | 0.85 | 0.45 | 0.50 | 0.54 | 0.63 | 0.65 | 0.65 | 0.73 | 0.76 | 0.69 | 0.45 | 0.45 | 0.57 | 0.82 | 0.71 |
| PK | 0.18 | 0.17 | -0.19 | -0.09 | 0.07 | -0.20* | 0.07 | 0.02 | 0.21* | -0.35** | -0.29** | 0.16 | -0.28** | 0.29* | -0.12 | -0.05 | -0.03 | . | 0.69 | 0.68 | 0.52 | 0.59 | 0.49 | 0.62 | 0.46 | 0.66 | 0.66 | 0.53 | 0.52 | 0.30* | 0.48 | 0.40 | 0.25** | 0.27** |
| PH | -0.02 | 0.04 | 0.33** | 0.42** | -0.25** | 0.52** | 0.22* | 0.21* | 0.11 | -0.07 | -0.11 | -0.02 | -0.03 | 0.19 | -0.08 | 0.07 | 0.50** | 0.04 | . | 0.81 | 0.51 | 0.52 | 0.54 | 0.55 | 0.65 | 0.67 | 0.69 | 0.68 | 0.65 | 0.43 | 0.52 | 0.55 | 0.80 | 0.69 |
| TK | -0.03 | -0.11 | -0.01 | 0.34** | 0.02 | 0.15 | 0.48** | 0.00 | -0.10 | 0.16 | 0.02 | 0.13 | -0.19 | 0.15 | -0.08 | 0.15 | 0.28* | 0.02 | 0.19 | . | 0.48 | 0.59 | 0.61 | 0.58 | 0.56 | 0.72 | 0.72 | 0.65 | 0.70 | 0.59 | 0.55 | 0.58 | 0.77 | 0.71 |
| IV | 0.14 | 0.02 | -0.15 | -0.01 | 0.07 | -0.09 | 0.02 | 0.09 | 0.13 | 0.33** | -0.01 | 0.29** | 0.02 | -0.34** | -0.20* | -0.25* | -0.23* | 0.02 | -0.01 | -0.10 | . | 0.37 | 0.51 | 0.51 | 0.60 | 0.58 | 0.56 | 0.49 | 0.62 | 0.32* | 0.36 | 0.54 | 0.45 | 0.44 |
| MI | 0.17 | 0.15 | 0.14 | 0.24* | 0.14 | 0.04 | 0.07 | -0.05 | 0.08 | -0.14 | -0.17 | 0.06 | -0.04 | 0.25* | 0.21* | 0.21* | -0.03 | 0.19 | 0.04 | 0.24* | -0.26** | . | 0.60* | 0.51 | 0.37 | 0.57 | 0.49 | 0.54 | 0.41 | 0.36 | 0.64 | 0.59 | 0.45 | 0.50 |
| NG | -0.06 | 0.06 | 0.24* | 0.10 | 0.29** | 0.24* | 0.07 | 0.09 | 0.26* | -0.02 | 0.13 | 0.07 | -0.27** | -0.14 | -0.18 | -0.17 | 0.00 | -0.08 | 0.01 | 0.21* | 0.02 | 0.20* | . | 0.57 | 0.55 | 0.45 | 0.53 | 0.60 | 0.45 | 0.55 | 0.64 | 0.64 | 0.64 | 0.63 |
| SG | 0.04 | -0.07 | -0.15 | 0.10 | 0.44** | -0.25* | -0.12 | -0.06 | 0.11 | -0.26* | 0.01 | 0.32** | -0.15 | 0.03 | ... | 0.05 | -0.08 | 0.17 | -0.26* | -0.04 | 0.05 | 0.02 | 0.13 | . | 0.45 | 0.49 | 0.52 | 0.63 | 0.46 | 0.61 | 0.34 | 0.63 | 0.57 | 0.56 |
| SA | 0.00 | -0.02 | 0.22* | -0.29** | 0.00 | 0.43** | -0.08 | 0.42** | -0.01 | 0.16 | -0.08 | -0.02 | 0.10 | -0.14 | -0.17 | -0.07 | 0.24* | -0.20 | 0.23* | -0.04 | 0.20* | -0.27** | 0.08 | -0.18 | . | 0.48 | 0.60 | 0.53 | 0.62 | 0.39 | 0.30 | 0.58 | 0.70 | 0.71 |
| IS | 0.54** | 0.23* | -0.07 | 0.20* | -0.12 | 0.30** | 0.28** | 0.22* | 0.20* | 0.20* | -0.11 | 0.39** | 0.24* | 0.20* | 0.30** | 0.20* | 0.01 | 0.18 | 0.12 | 0.28** | 0.16 | 0.14 | -0.15 | -0.15 | -0.12 | . | 0.60 | 0.49 | 0.64 | 0.32 | 0.50 | 0.47 | 0.64 | 0.54 |
| JO | -0.03 | 0.02 | -0.02 | -0.37** | 0.10 | 0.05 | 0.19* | -0.13 | -0.05 | 0.02 | -0.03 | -0.06 | -0.08 | -0.21 | -0.10 | -0.16 | -0.15 | 0.02 | -0.18 | -0.04 | 0.12 | -0.04 | -0.01 | -0.20* | 0.10 | -0.04 | . | 0.65 | 0.78 | 0.59 | 0.32 | 0.55 | 0.73 | 0.69 |
| MC | -0.13 | 0.09 | 0.04 | 0.25* | 0.03 | -0.15 | -0.24** | 0.05 | 0.11 | 0.00 | 0.50** | -0.04 | -0.11 | -0.14 | 0.02 | -0.01 | 0.1 | -0.31** | -0.13 | -0.21* | -0.05 | 0.08 | 0.18 | -0.03 | -0.07 | -0.30** | -0.11 | . | 0.59 | 0.61 | 0.48 | 0.64 | 0.84 | 0.79 |
| HN | 0.08 | 0.07 | -0.14 | ... | -0.14 | 0.27* | 0.16 | -0.23* | -0.37** | 0.28** | -0.01 | 0.03 | 0.19 | -0.22* | 0.26** | 0.06 | -0.17 | -0.31** | -0.21 | -0.01 | 0.26** | -0.23* | -0.19 | -0.28** | 0.16 | 0.10 | 0.32** | -0.21* | . | 0.57 | 0.39 | 0.58 | 0.84 | 0.77 |
| LT | -0.47** | -0.47** | -0.16 | -0.02 | 0.11 | -0.16 | 0.20 | -0.24 | -0.30* | -0.25 | 0.31* | -0.20 | ... | 0.21 | ... | -0.31* | -0.31* | -0.39** | -0.29* | 0.13 | -0.41** | -0.24 | 0.10 | 0.21 | -0.30* | -0.43** | 0.12 | 0.20 | ... | . | 0.50 | 0.59 | 0.64 | 0.68 |
| MK | -0.02 | -0.02 | 0.21 | 0.43** | -0.19 | 0.00 | 0.11 | -0.02 | 0.22 | -0.02 | 0.21 | -0.02 | ... | 0.18 | ... | -0.01 | 0.14 | -0.09 | 0.25 | 0.24 | -0.23 | 0.22 | 0.27 | -0.29 | -0.36* | 0.08 | -0.30* | 0.25 | ... | 0.03 | . | 0.41 | 0.55 | 0.45 |
| RM | 0.01 | 0.07 | 0.28** | 0.15 | 0.44** | 0.20 | 0.16 | 0.12 | -0.14 | 0.39** | 0.19 | 0.00 | 0.03 | 0.06 | 0.13 | 0.18 | -0.04 | -0.35** | -0.07 | 0.03 | 0.09 | 0.18 | 0.26** | 0.20 | 0.14 | -0.16 | -0.04 | 0.19 | 0.05 | 0.15 | -0.12 | . | 0.82* | 0.79** |
| SX | -0.24 | -0.24 | 0.40** | 0.36* | 0.02 | 0.26 | 0.19 | 0.47** | 0.00 | 0.36* | 0.62** | -0.06 | ... | 0.22 | ... | 0.04 | 0.24 | -0.52** | 0.28 | 0.32* | -0.35* | 0.18 | 0.42** | 0.02 | 0.24 | 0.08 | -0.16 | 0.29 | ... | 0.25 | 0.35* | 0.60** | . | 0.91** |
| SJ | -0.31* | -0.31* | 0.33* | 0.36* | 0.29* | 0.30* | 0.07 | 0.27 | -0.23 | 0.37** | 0.41** | 0.06 | ... | 0.11 | ... | -0.05 | 0.1 | -0.47** | 0.10 | 0.23 | -0.23 | 0.21 | 0.35* | 0.01 | 0.33* | -0.11 | 0.10 | 0.41** | 0.34* | 0.35* | 0.06 | 0.56** | 0.70** | . |
| $\mu_s$ | 0.75 | 0.74 | 0.70 | 0.53 | 0.60 | 0.68 | 0.70 | 0.71 | 0.67 | 0.61 | 0.81 | 0.44 | 0.82 | 0.39 | 0.96 | 0.90 | 0.91 | 0.74 | 0.87 | 0.86 | 0.52 | 0.51 | 0.55 | 0.68 | 0.60 | 0.68 | 0.82 | 0.79 | 0.78 | 0.57 | 0.39 | 0.60 | 0.84 | 0.73 |

Significance is denoted by: * if $p < 0.05$ and ** if $p < 0.01$.

Thirdly, the synchronisation between business cycles of developing countries that are in different regions is examined. From Table 2.12 it is evident that the Latin American countries have the most concordant business cycles; there is significant concordance between Brazil and the Philippines and South Africa, between Argentina and Macedonia, between Peru and the Philippines, between Barbados and Senegal and Romania, between Colombia and Turkey, between Chile and Malaysia and South Africa, between Peru and Romania and Slovenia, between Trinidad and Tobago and India, Morocco, the Slovak Republic and Slovenia, and finally between Uruguay and Israel. With the exception of the significant synchronisation of the Hong Kong and Malawian business cycles, there is no significant concordance between the Asian, the African or the Eastern European business cycles.

Finally, it is interesting to note the statistical significance of the low concordance values between Lithuania and the US, the UK, Côte d'Ivoire, Mexico and Pakistan. It indicates that the relationship between these countries' business cycles and the Lithuanian business cycle is significantly countercyclical. For example, the concordance statistic between Lithuania and the US is 0.34 which implies that 66% of the time the Lithuanian cycle is in a different phase to the US. This countercyclical relationship is supported by the significant negative correlations between these countries. There are further significant countercyclical relationships between Pakistan and the Slovak Republic and Slovenia.

## 2.7 CONCLUSION

The classical business cycles of thirty-two developing countries have been identified using the Bry-Boschan (1971) dating algorithm and characterised using the methodology of Harding and Pagan (2002). This analysis has revealed several key findings, which expand the current knowledge of developing country business cycles and should prove useful to theorists and policy makers alike.

Firstly, the business cycles of developing countries are not significantly shorter than those of the developed countries; rather it depends on country specific factors. However, there are some clear patterns between regional groups. The Latin American and African countries tend to have significantly shorter business cycles than those of the developed countries. The North African and Eastern European cycles are on a par with the developed country cycles, whilst the Asian business cycles are substantially longer.

Secondly, the amplitude of both contraction and expansion phases is significantly greater in the developing countries than in the developed countries. The Asian countries have the greatest expansion phase amplitude, whilst the African and Eastern European countries have the greatest contraction phase amplitudes. This corresponds with both the rapid rates of economic growth experienced by most Asian countries in the second half of the twentieth century, and with the consistently poor growth rates of the African and East European countries.

Thirdly, observation of the timing of peaks and troughs suggests that business cycles are fairly synchronised amongst the Latin American countries and amongst the Asian countries. There is a clear relationship between the timing of business cycle fluctuations and periods of significant regional crises, such as the Asian financial crises. However, as noted by Rand and Tarp (2002), the more specific timing of the start of a recession appears to be determined by country-specific factors.

Finally, there are no clear patterns of concordance either within regions or between developed and developing countries. However, there are a few developing countries which are significantly synchronous with the developed countries. Bangladesh, Hong Kong, India, Israel, Mexico, South Korea and Uruguay are significantly concordant with the US business cycle; whilst the business cycles of Brazil and the Philippines are significantly concordant with the Japanese business cycle.

However, these business cycle characteristics are only concurrent with the *classical* cycle definition of the business cycle. Thus, to fully characterise the developing country business cycle it is also necessary to examine the statistical properties, or stylised facts, of the *growth* cycle, which will be conducted in the subsequent chapter.

# CHAPTER 3

## *"Developing Country Business Cycles: Revisiting the Stylised Facts"*

### 3.1. INTRODUCTION

In 1990, Kydland and Prescott established the first set of "stylised facts" for business cycles in the developed world, based on their research into the US business cycle. This led to a burgeoning of literature freshly interested in the statistical properties of business cycles. However, this literature predominantly concentrated on the business cycles of industrialised countries. A noticeable exception to this pattern was the seminal paper by Agénor, McDermott and Prasad in 2000 that established a set of stylised facts for the business cycles of developing countries, and it is these stylised facts that are the subject of interest in this chapter.

Stylised facts, such as the ones conveyed by Kydland and Prescott (1990) and Agénor *et al.* (2000) are an important stepping-stone to the construction of a successful theoretical model, as they are often used as the empirical basis for formulating and validating theoretic models of the business cycle. Therefore, it is extremely important to ensure that the stylised facts are as accurate as possible. In the case of industrialised countries this is not a huge problem as there is a vast literature, providing substantial country coverage, and with the majority of the findings being robust between countries and authors. However, this is not the case for developing countries.

Since Agénor *et al.* (2000) there have been numerous papers looking at developing countries, such as Rand and Tarp (2002), Neumeyer and Perri (2005) and Aguar and Gopinath (2007). However the majority of these papers have remarkably small data sets, for example, Agénor *et al.* (2000) have a sample of twelve middle-income countries, Rand and Tarp (2002) have fifteen, whilst Neumeyer and Perri (2005) have only five developing countries in their sample. Noticeable exceptions to this rule are papers by Pallage and Robe (2001) and Bulir and Hamann (2001) which have 63 and 72 developing countries, respectively, in their samples. These papers, however, concentrate purely on stylised facts relating to foreign aid and consequently their datasets are not applicable in this analysis.[1] A fundamental feature that is clearly apparent from reviewing these papers is that there is not

[1] Pallage and Robe (2001) employ annual data for only two variables: GDP per capita and official development assistance. Similarly, Bulir and Hamann (2001) use annual data on aid, fiscal revenue and GDP. Neither of these datasets is sufficient to conduct a comprehensive analysis of developing country business cycles and the related stylised facts.

the same consistency of findings as for the industrialised countries; only some of the stylised facts reported in Agénor *et al.* (2000) are similarly reported in the subsequent literature and there is less consensus between countries, such that the results clearly depend on the countries included in the study. Motivated by this lack of consistency and the importance of business cycle stylised facts, this chapter aims to generalise the business cycle statistics for a much larger sample of developing countries, and secondly to construct a more comprehensive set of stylised facts for use in subsequent theoretic modelling of developing country business cycles.

In section two, this chapter briefly reviews the literature and documents the stylised facts for both industrialised and developing country business cycles. Section three details the methodology employed in order to carry out the statistical analysis required to compute such stylised facts, whilst section four outlines the data sources and the countries included in this study. Section five documents the empirical regularities identified within the persistence, volatility and cross-correlation analysis, and compares these results to the stylised facts reported in the literature. Finally, section six concludes and provides a summary of the main stylised facts emerging from this study.

## 3.2. LITERATURE REVIEW – WHAT ARE THE STYLISED FACTS?

The stylised facts of industrialised country business cycles are well established; a vast body of literature documents a wide range of empirical regularities amongst these countries (Kydland and Prescott, 1990; Backus and Kehoe, 1992; Backus, Kehoe and Kydland, 1995; King and Watson, 1996; Basu and Taylor, 1999; Chari *et al.*, 2002). However, this is not the case for developing countries. It is therefore important when trying to determine a set of developing country stylised facts, to first understand the key features of the industrialised country business cycles. These empirical regularities will then serve as benchmarks for comparison and identification of developing country stylised facts.

The empirical regularities, or stylised facts, for the industrialised countries include:

- Persistent real output fluctuations and real exchange rate fluctuations (in recent years). Real exchange rates are also typically fairly volatile.
- Volatility of output, consumption and net exports very similar (consumption and net exports slightly less volatile than output) whilst investment is consistently 2 to 3 times

more volatile and government expenditures are significantly less volatile than output (by around half).

- A remarkably stable relationship between output, consumption and inflation.
- Consumption, investment, employment, inflation and money velocity all generally procyclical.
- Increasing procyclicality of the real wage, whilst price is consistently countercyclical and inflation is generally procyclical.
- Ratio of net exports to output typically countercyclical.
- Government expenditures typically acyclical.
- International comovements in output, consumption and investment, but output correlations are generally higher than consumption correlations.
- Correlations between the real exchange rate and aggregate quantities, in particular relative consumption, are fairly small.

**Table 3.1 Properties of Business Cycles in OECD Countries (1970:1 – 1990:2)**

| Country | St. Dev (%) | | Ratio St. Dev to St. Dev of Y | | | | Correlation with Y | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | y | nx | c | i | g | n | y | c | i | g | nx | n |
| Australia | 1.5 | 1.2 | 0.7 | 2.8 | 1.3 | 0.3 | 0.6 | 0.4 | 0.7 | 0.2 | 0 | 0.1 |
| Austria | 1.3 | 1.2 | 1.1 | 2.9 | 0.4 | 1.2 | 0.6 | 0.7 | 0.8 | -0.2 | -0.5 | 0.6 |
| Canada | 1.5 | 0.8 | 0.9 | 2.8 | 0.8 | 0.9 | 0.8 | 0.8 | 0.5 | -0.2 | -0.3 | 0.7 |
| France | 0.9 | 0.8 | 1.0 | 3.0 | 0.7 | 0.6 | 0.8 | 0.6 | 0.8 | 0.3 | -0.3 | 0.8 |
| Germany | 1.5 | 0.8 | 0.9 | 2.9 | 0.8 | 0.6 | 0.7 | 0.7 | 0.8 | 0.3 | -0.1 | 0.6 |
| Italy | 1.7 | 1.3 | 0.8 | 2 | 0.4 | 0.4 | 0.9 | 0.8 | 0.9 | 0 | -0.7 | 0.4 |
| Japan | 1.4 | 0.9 | 1.1 | 2.4 | 0.8 | 0.4 | 0.8 | 0.8 | 0.9 | 0 | -0.2 | 0.6 |
| Switzerland | 1.9 | 1.3 | 0.7 | 2.3 | 0.5 | 0.7 | 0.9 | 0.8 | 0.8 | 0.3 | -0.7 | 0.8 |
| UK | 1.6 | 1.2 | 1.2 | 2.3 | 0.7 | 0.7 | 0.6 | 0.7 | 0.6 | 0.1 | -0.2 | 0.5 |
| US | 1.9 | 0.5 | 0.8 | 3.3 | 0.8 | 0.6 | 0.9 | 0.8 | 0.9 | 0.1 | -0.4 | 0.9 |
| Europe | 1.0 | 0.5 | 0.8 | 2.1 | 0.5 | 0.9 | 0.8 | 0.8 | 0.9 | 0.1 | -0.3 | 0.3 |

Source: Backus, Kehoe and Kydland (1995, p. 334; Table 11.1)

Examination of Table 3.1 reveals that the business cycles of all the countries have fairly similar properties; investment is clearly 2 to 3 times more volatile than output, consumption and net exports; real output, consumption, investment and real wages are all procyclical, whilst net exports and government expenditures are generally countercyclical and acyclical respectively.

The number of empirical studies for developing countries is rather more limited, however includes works by Agénor *et al.* (2000), Rand and Tarp (2002), Neumeyer and Perri (2005) and Aguar and Gopinath (2007). In 2000, Agénor *et al.* established a set of stylised facts for the business cycles of developing countries and this has become the seminal work upon which most subsequent studies compare their findings.

Based on a sample of twelve middle-income developing countries (Korea, Malaysia, Mexico, Morocco, Nigeria, the Philippines, Tunisia, Turkey and Uruguay) for the period 1978:1 – 1995:4, Agénor *et al.* (2000) found significant differences from industrialised country business cycles. Their key findings, or stylised facts, and how these compare to the stylised facts for the industrialised countries are as follows. Firstly, output volatility varies substantially across developing countries and is on average much higher than the level typically observed in industrial countries. However, developing countries also show considerable persistence in output fluctuations as observed in the industrialized countries. Secondly, that activity in industrial countries, as measured by world output and world real interest rate, has a significantly positive influence on output in most developing countries. Thirdly, government expenditures and the fiscal impulse appear to be countercyclical whilst there is no distinct pattern in government revenue; it is acyclical in some countries in their sample and significantly countercyclical in others. Fourthly, there is evidence of procyclical real wages as in the developed countries. Fifthly, whilst prices are widely documented as being countercyclical in the industrialised countries, there appears to be no consistent relationship between either output and prices or output and inflation in developing countries. Sixthly, contemporaneous correlations between money and output are broadly positive, but not very strong, which is in contrast to the evidence for many industrial countries, and suggests that there is need to examine the key role often assigned to monetary policy in stabilization programs in developing countries. Furthermore, whilst the velocity of broad money is weakly procyclical in most industrialised countries it appears to be strongly countercyclical in this sample of developing countries. Seventhly, there is no robust relationship between the trade balance and output. Where it is procyclical, this "*may indicate that fluctuations in industrial output are driven by export demand and that imports are not as sensitive to domestic demand fluctuations as they are in industrial countries*" (Agénor *et al.*, 2000, p.280). Furthermore, terms of trade are strongly procyclical suggesting much of the fluctuation in output in developing countries can be explained by terms of trade shocks, as has been suggested by Mendoza (1995). However, it is important to note that this is based on results for just three of the sample countries. Finally, there appears to be no systematic pattern for the correlation of nominal or real effective exchange rates and industrial output.

A subsequent paper by Rand and Tarp (2002) added to this work by examining the duration of the business cycles and the volatility of the variables in addition to the cross-correlation analysis. Based on a sample of fifteen developing countries (five in Sub-

Saharan Africa, five in Latin America and five in Asia and North Africa), with a quarterly dataset for the duration analysis (1980:1 – 1999:4) and an annual dataset for the cross-correlation and volatility analysis (1970 – 1997) they report the following key results. Firstly, that developing country business cycles are significantly shorter than those of the industrialised countries; however, Chapter 2 of this thesis reveals this not to be the case. Secondly, that output is more volatile than in developed countries, but by no more than 15 to 20%, whilst consumption is generally more volatile than output, which is the opposite to what is found in developed countries. Thirdly, that consumption and investment are strongly procyclical, which is consistent with what is observed in the industrialised countries. However, the pattern is not so clear for prices and inflation; prices are not consistently countercyclical as for the industrialised countries and furthermore, inflation appears to have the same cyclical pattern as CPI, such that it is countercyclical for the majority of the sample, whilst in the developed countries inflation is generally procyclical. Fourthly, there is no consistent relationship between government consumption and output such that "*governments seem to have a limited stabilising role on the economy*" (Rand and Tarp, 2000, p.2084), but this is similar to the observation in industrialised countries; see Table 3.1. Fifthly, money aggregates are generally procyclical, as in industrialised countries. In addition, there is some indication of a positive relationship between domestic credit and output. Sixthly there is no clear pattern when it comes to the terms of trade, whereas in industrialised countries there is generally positive correlation between lagged values of terms of trade and output. Finally, aid and foreign direct investment (FDI) appear to be highly volatile and show no signs of being procyclical, which is the opposite of the findings of Pallage and Robe (2001) and Bulir and Hamann (2001).

Other recent studies by Aguar and Gopinath (2007) and Neumeyer and Perri (2005) add some interesting finding to the developing country stylised facts. Firstly, based on a sample of thirteen countries (Argentina, Brazil, Ecuador, Israel, Korea, Malaysia, Mexico, Peru, Philippines, Slovakia, South Africa, Thailand and Turkey) Aguar and Gopinath (2007) report a similar degree of output persistence but that output is twice as volatile as in the industrialised countries, whilst consumption is around 40% more volatile. Secondly, that the ratio of investment volatility to output volatility is not dissimilar from that found in the developed countries. Thirdly, that net exports are around 3 times more volatile and strongly countercyclical, as opposed to weakly countercyclical in the developed countries; and finally, that consumption and investment strongly procyclical, as found in the developed countries.

Neumeyer and Perri (2005) find the very interesting result that real interest rates in developing countries are countercyclical and lead the cycle whereas they find no such pattern with the developed countries; real interest rates are mildly procyclical. They also find the volatility of real interest rates to be on average 40% higher in the developing countries. This is based on a sample of five developing countries (Argentina, Brazil, Korea, Mexico and the Philippines) and five developed countries (Australia, Canada, Netherlands, New Zealand, and Sweden).

In summary, the key features that the literature appears to hail as the stylised facts for developing countries are:

- Business cycles are generally shorter and more volatile than those of the industrialised countries.
- Output is more volatile than in developed countries, but there is a similar degree of persistence in output fluctuations.
- Consumption is more volatile than output in developing countries, opposite of developed country case.
- Activity in developed countries, as measured by world output and world real interest rate, has a significantly positive influence on output in most developing countries.
- Prices are not consistently countercyclical, as for developed countries, and inflation is not consistently procyclical.
- Consumption, investment, real wages, money aggregates are all generally procyclical, which is consistent with the findings for developed countries. However these relationships are typically weaker in the developing country samples.
- Real interest rates are countercyclical and lead the cycle, whereas real interest rates are typically mildly procyclical in developed countries. Real interest rates are also more volatile in the developing countries.
- No clear relationships in terms of government expenditure, nominal or real effective exchange rates or terms of trade and output.

However, these facts are formed on the basis of very small samples of developing countries and even based on these small samples there appears to be less consistency between countries than for the industrialised country samples. Thus, this chapter proceeds to an empirical analysis to examine whether the developing country stylised facts hold for a much larger sample of developing countries, or whether they are robust only for specific subsets of countries as chosen by these authors.

## 3.3. METHODOLOGY

### *3.3.1. Detrending*

The first step is to deseasonalize the data. This is done using the Census Bureau's X-12 ARIMA seasonal adjustment program. This is important for the correct implementation of the subsequent detrending procedure. For example, the HP filter will pass all of the series variations associated with the quarterly seasonal frequencies. Given that seasonal variation should not contaminate the cycle, for seasonal series the HP filter has to be applied to seasonally adjusted series (Kaiser and Maravall, 2001).

Once deseasonalized, logarithms are taken of the data, as is common practice in the business cycle literature, and then the series are filtered to extract the stationary (cyclical) component and the non-stationary (trend) component. This is carried out because, following Lucas (1977), the business cycle component of a variable is defined as its deviation from trend. Furthermore, certain empirical characterisations of the data, including cross-correlations, are only valid if the series are stationary (Agénor *et al.*, 2000). In choosing a detrending technique, most researchers appear to opt for either the Hodrick-Prescott (HP) filter (Hodrick and Prescott, 1997) or the band-pass (BP) filter (Baxter and King, 1999), of which the HP filter is the most common choice:

> *"One can say that the HP filtering of X11-SA series has become the present paradigm for business-cycle estimation in applied work"* (Kaiser and Maravall, 2001, p.66)

The HP filter is a linear filter designed to optimally extract a non-stationary trend component, which changes smoothly over time, from an observed non-stationary time series. Assuming that the (deseasonalized) time series $y_t$ can be decomposed into an additive cyclical component $c_t$ and trend component $g_t$, extracting the trend component will yield a stationary cyclical component, which can be used by researchers to analyse the business cycle.

$$y_t = c_t + g_t \qquad \text{for } t = 1, \ldots, T$$

The trend component, $g_t$, is determined by minimising:

$$\sum_{t=1}^{T} c_t^2 + \lambda \sum_{t=2}^{T} \left[ (g_t - g_{t-1}) - (g_{t-1} - g_{t-2}) \right]^2$$

Where, the smoothing parameter $\lambda$ penalizes variability in the trend.

The smoothing parameter λ is chosen *a priori*

> "*… to isolate those cyclical fluctuations which belong to the specific band which the researcher wants to investigate*" (Canova, 1998, p.485)

The HP filter has the advantage that it does not amplify high-frequency noise (unlike a standard first differencing approach). However, it does have several disadvantages which mean that the method of detrending an economic time series by means of the HP filter should be used with care. Firstly, it allows much of the high frequency noise to be left outside the business cycle frequency band; the low-frequency BP filter has been adjusted to account for this. However, as a result it tends to underestimate the cyclical component (Rand and Tarp, 2002). Secondly, the HP filter gives imprecise estimates of the trend at the end-points of the time series. Thirdly, the HP filter cannot capture structural breaks in the data series. Fourthly, the HP filter can induce spurious cycles in the filtered series. And finally, the HP filter relies on an arbitrary choice of the smoothing parameter λ.

This final point has caused much controversy over what the optimal value of λ should be. The default choice is that of λ = 1600 for quarterly data as computed, rather arbitrarily, by Hodrick and Prescott (1997):

> *"Our prior view is that a 5 percent cyclical component is moderately large, as is a one-eighth of 1 percent change in the growth rate in a quarter. This led us to select* $\sqrt{\lambda}$ *= 5/(1/8) = 40 or λ = 1600 as a value for the smoothing parameter"* (p.4)

However, Kydland and Prescott (1990), amongst others, find this value to be reasonable for quarterly time series and Hodrick and Prescott (1997) find that their results are little changed if λ is changed by a factor of four to 400 or 6400.

Using the default value of λ = 1600 Canova (1998) finds that:

> *"The HP1600 filter produces results which are similar to those obtained with conventional band-pass filters (e.g. frequency domain masking the low frequency components of the data or standard MA filters) and concentrates the attention of the researcher on cycles with an average duration of 4–6 yr"* (p.508)

Rand and Tarp (2002) find that "*the optimal value of λ is between five and 377 when quarterly data are used*" (p.2074) for their sample of 15 developing countries. However, this draws on their finding that business cycles in developing countries are much shorter than those in developed countries.[2] As discussed in Chapter 2, there is no clear significant difference between the duration of developing and developed country business cycles. The finding of Rand and Tarp (2002) results from their comparison of developing country business cycles measured from industrial production data with the standard results for developed country cycles, which are almost certainly calculated using real GDP. Thus, since the average length of cycles in this study is approximately 5 years, with a minimum length of 2.2 years and a maximum of 13.8 years, this choice of λ appears to be consistent with this sample.

Despite all the criticisms, the HP filter remains the most commonly applied detrending technique in the business cycle literature and thus is the one applied here, with smoothing parameter $\lambda = 1600$. And, as Kaiser and Maravall (2001) note:

> *"…a positive feature of the generalized use of the HP filter is that it has brought homogeneity in method, so that the effect of the choice of filter has been stabilized"* (p.80)

### *3.3.2. Volatility, Persistence and Correlations*

After deseasonalizing and detrending the series' to obtain the cyclical components, the statistical analysis of the data can be carried out.[3] It should be noted that, as is standard in the literature, in the subsequent analysis all references to the variables refer to the cyclical components.

The statistical analysis concentrates on those statistical features which are commonly quoted as the stylised facts of business cycles, namely volatility, persistence and cross-correlations.

Volatility, or relative volatility, reports the magnitude of fluctuations of the variables of interest. Volatility is measured by the standard deviation of the variable whilst relative volatility is the ratio between the volatility of the variable of interest and the volatility of industrial production. A relative volatility of one implies that the variable has the same cyclical amplitude as the aggregate business cycle (as proxied by industrial production); whilst a relative volatility greater than one implies that the variable has greater cyclical amplitude than the aggregate business cycle.

[2] They find the length of business cycles in their sample to be between 7.7 and 12 quarters compared with the 24 and 32 quarters reported for developed countries.

[3] PCGive was used for the purposes of deseasonalizing and detrending the data. All subsequent statistical analysis in this chapter was performed using STATA.

The persistence of the cyclical component of a variable is measured by its autocorrelation function. The significance of the persistence is measured using the Ljung-Box portmanteau (Q) test for white noise; if the statistic has $p > 0.05$ then this is not significant and is considered to imply that there is little or no persistence in the cyclical component.

Finally, following Agénor *et al.* (2000), the degree of co-movement of the variables of interest ($y_t$) with industrial production ($x_t$) is measured by the magnitude of the correlation coefficient $\rho(j), j \in \{0, \pm1, \pm2, ...\}$. A series $y_t$ is considered to be pro-cyclical if the contemporaneous coefficient $\rho(0)$ is positive, acyclical if the contemporaneous coefficient $\rho(0)$ is zero and countercyclical if the contemporaneous coefficient $\rho(0)$ is negative.

The cross-correlation coefficients $\rho(j), j \in \{0, \pm1, \pm2, ...\}$ indicate whether a series $y_t$ leads, lags or is synchronous with the business cycle ($x_t$). Series $y_t$ is considered to lead the cycle by j periods if the largest cross-correlation coefficient arises for a negative j (i.e. a lagged value of $y_t$), be synchronous with the cycle if the largest cross-correlation coefficient arises at $j = 0$ or lag the cycle by j periods if the maximum cross-correlation arises for a positive j. For example, let $y_t$ be a procyclical series that leads the business cycle, as in Figure 3.1(c). In this case the maximum positive cross-correlation coefficient will occur for the correlation between $x_t$ and $y_{t-j}$. Figure 3.1 illustrates a procyclical series ($y_t$) that either lags, is synchronous or leads the business cycle ($x_t$), whilst Figure 3.2 shows this for a countercyclical series.

## 3.4. DATA

There are thirty-two developing countries included in this sample, of which there are five African countries (Côte d'Ivoire, Malawi, Nigeria, Senegal and South Africa), four North African and Middle Eastern countries (Israel, Jordan, Morocco and Tunisia), nine Latin American countries (Argentina, Barbados, Brazil, Chile, Colombia, Mexico, Peru, Trinidad and Tobago, and Uruguay), eight Asian countries (Bangladesh, Hong Kong, India, South Korea, Malaysia, Pakistan, the Philippines and Turkey) and six Central and Eastern European countries (Hungary, Lithuania, Macedonia, Romania, the Slovak Republic and Slovenia). In addition, three developed countries, the United Kingdom, the United States and Japan, are included as benchmarks upon which to compare the results for the developing countries. For a detailed discussion of the countries included, see Chapter 2.

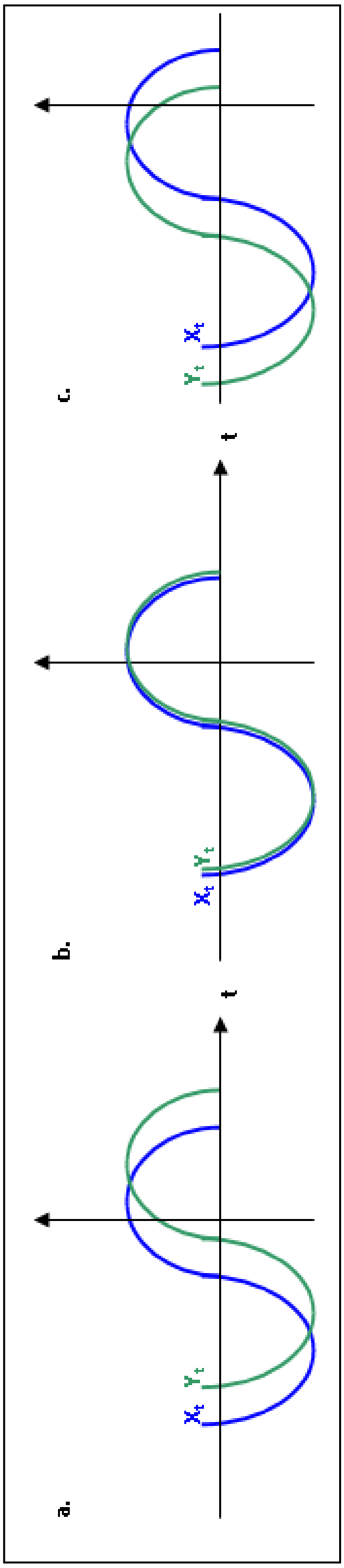



Figure 3.1 Series $y_t$ is procyclical and (a) lags the cycle, (b) is synchronous with the cycle, (c) leads the cycle

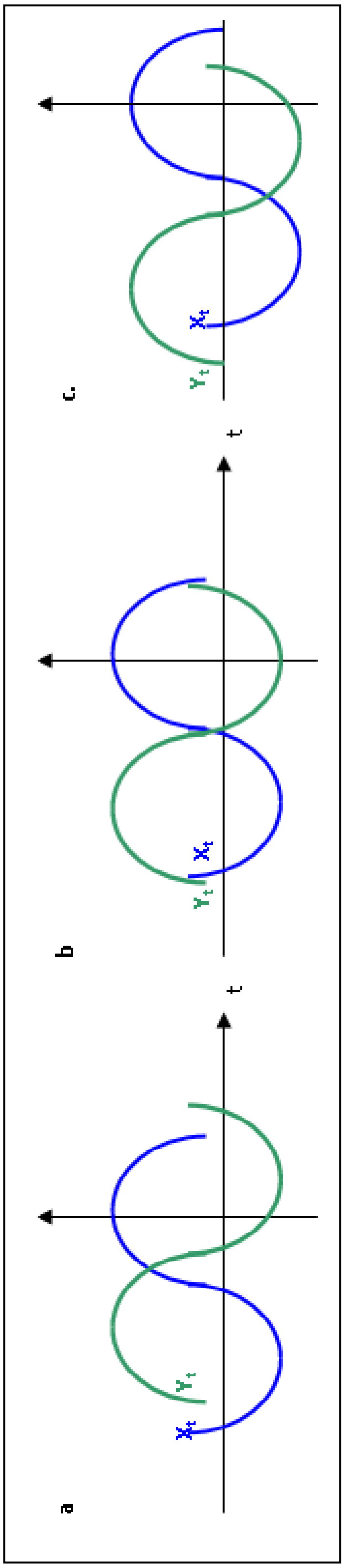



Figure 3.2 Series $y_t$ is countercyclical and (a) lags the cycle, (b) is synchronous with the cycle, (c) leads the cycle

As discussed in Chapter 2, reliable real GDP data, which is usually used as a measure of the aggregate business cycle, is not available for a large number of developing countries, especially where quarterly data is concerned. Thus, the suggestion of Agénor *et al.* (2000) is followed, and indexes of industrial production are used as a suitable proxy for the aggregate business cycle.

The other variables selected for analysis are also selected following Agénor *et al.* (2000). They include price variables (the consumer price index, inflation and the real wage rate); public sector variables (government expenditure, government revenue and the fiscal impulse); trade variables (imports, exports, trade balance and terms of trade); exchange rates (real and nominal effective exchange rates); money variables (broad money, private sector credit, interest rate and gross fixed capital formation); and finally, world output and world real interest rate to represent economic activity in the main industrial countries.

The primary data source is the International Monetary Fund (IMF) International Financial Statistics (IFS) database. In the few cases where data was not available through the IMF, the variables were sought through the countries' national statistics databases. The sample period varies depending on the availability of quarterly data for each country. However, there is good data coverage for the period from 1980 to 2004 across countries.[4] Details of the data, including the corresponding IMF IFS series codes, can be found in Appendix A.

## 3.5. EMPIRICAL RESULTS

### *3.5.1. Persistence*

A key empirical feature of the industrialised countries' business cycles is the significant persistence of output fluctuations, and the existing stylised facts for developing countries suggest that these cycles also exhibit significant output persistence. There is also evidence of significant persistence of real exchange rate fluctuations in the industrialised countries, although there have been few, if any, empirical studies on this for the developing countries. These two empirical features have drawn much theoretical consideration, and most models incorporate nominal rigidities in the form of sticky prices and sticky wages in-order to explain these features. If such models are also to be applied to developing country business cycles, it is necessary to examine whether prices and nominal wages are indeed sticky in these countries.

[4] For a discussion of why this time-frame is appropriate, please see Chapter 2.

Thus, this section examines both the persistence of output and real exchange rate fluctuations for the developing countries, and the persistence of both the consumer price index and real wage. Table 3.2 reports the persistence of output and real effective exchange rates (REER), whilst Table 3.3 reports the persistence of the consumer price index and the nominal wage.

Examination of the autocorrelations of output reveals that for most of the developing countries there is significant output persistence. However, the magnitude of this persistence is somewhat lower than for the industrialised countries; for example, the average autocorrelation coefficient at lag one for the industrialised countries is 0.84 whilst it is just 0.59 for the developing countries, furthermore at lag four the average coefficient for the industrialised countries is 0.146, but this has dropped to zero for the developing countries. There are a few exceptions amongst the developing countries, for which output is not significantly persistence, namely Malawi, Morocco and Macedonia.

Secondly, examination of the autocorrelations of the real effective exchange rates reveals that, with the sole exception of the Slovak Republic, all the developing countries exhibit significant real exchange rate persistence. However, the magnitude of this persistence is slightly lower than that for the developed countries; the average autocorrelation coefficient at lag one for the US, UK and Japan is 0.84, whilst it is 0.701 for the developing countries.

Thirdly, for all of the countries, with the exception of Uruguay, there is significant price persistence, although again this persistence is of a lower magnitude than for the industrialised countries. The lack of price persistence observed in Uruguay is explained by the extremely high average annual rate of inflation observed over the sampling period.[5] Finally, the persistence of the nominal wage is examined. In this case, all of the developing countries display significant nominal wage persistence (or stickiness), but as with all the other variables, this is of a significantly lower magnitude than for the industrialised countries.

The finding of significant price and wage persistence is important, because it justifies the use of theoretical models with staggered prices and wages for the modelling of developing country business cycles. However, the fact that this persistence is of a lower magnitude must be taken into consideration, for example by implementing shorter contract durations.

[5] The average annual inflation rate in Uruguay for the period 1980:1 – 2002:3 is 46%

**Table 3.2 Persistence of Output and the Real Effective Exchange Rate (REER)**

| Region | Country | Output | | | | | REER | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Lag 1 | Lag 2 | Lag 3 | Lag 4 | Q | Lag 1 | Lag 2 | Lag 3 | Lag 4 | Q |
| **OECD** | US | 0.886 | 0.672 | 0.440 | 0.199 | 517.8** | 0.883 | 0.639 | 0.503 | 0.349 | 417.4** |
| | UK | 0.756 | 0.549 | 0.372 | 0.147 | 451.6** | 0.795 | 0.541 | 0.334 | 0.121 | 409.1** |
| | Japan | 0.891 | 0.671 | 0.388 | 0.091 | 396.6** | 0.835 | 0.621 | 0.460 | 0.264 | 650.7** |
| **Africa** | Côte D'Ivoire | 0.432 | 0.149 | 0.189 | 0.047 | 142.6** | 0.689 | 0.429 | 0.222 | 0.042 | 161.3** |
| | Malawi | 0.351 | -0.036 | -0.108 | -0.029 | 18.8 | 0.435 | 0.265 | -0.028 | -0.014 | 44.2** |
| | Nigeria | 0.641 | 0.351 | 0.185 | 0.056 | 325.9** | 0.846 | 0.648 | 0.441 | 0.230 | 262.9** |
| | Senegal | 0.385 | 0.074 | 0.039 | -0.164 | 76.0** | … | … | … | … | … |
| | South Africa | 0.814 | 0.641 | 0.442 | 0.206 | 598.0** | 0.760 | 0.501 | 0.337 | 0.117 | 214.1** |
| **North Africa** | Israel | 0.635 | 0.427 | 0.208 | -0.032 | 218.3** | 0.679 | 0.323 | 0.057 | -0.128 | 142.9** |
| | Jordan | 0.452 | 0.020 | -0.175 | -0.310 | 62.6* | … | … | … | … | … |
| | Morocco | 0.041 | 0.188 | 0.207 | -0.196 | 53.6 | 0.629 | 0.164 | -0.174 | -0.261 | 160.9** |
| | Tunisia | 0.422 | 0.233 | 0.138 | -0.104 | 71.3** | 0.818 | 0.623 | 0.461 | 0.263 | 391.5** |
| **Latin America** | Argentina | 0.808 | 0.584 | 0.329 | 0.070 | 99.6** | … | … | … | … | … |
| | Barbados | 0.614 | 0.418 | 0.155 | 0.018 | 168.7** | … | … | … | … | … |
| | Brazil | 0.632 | 0.153 | -0.114 | -0.267 | 91.9** | … | … | … | … | … |
| | Colombia | 0.565 | 0.341 | 0.144 | -0.049 | 133.2** | 0.798 | 0.590 | 0.392 | 0.161 | 182.1** |
| | Chile | 0.767 | 0.551 | 0.348 | 0.132 | 521.5** | 0.771 | 0.556 | 0.353 | 0.138 | 538.1** |
| | Mexico | 0.800 | 0.603 | 0.370 | 0.158 | 377.6** | 0.610 | 0.447 | 0.295 | 0.130 | 377.6** |
| | Peru | 0.817 | 0.556 | 0.312 | 0.142 | 325.2** | … | … | … | … | … |
| | Trinidad | 0.415 | 0.248 | 0.038 | -0.184 | 91.6** | 0.814 | 0.620 | 0.474 | 0.325 | 518.1** |
| | Uruguay | 0.635 | 0.574 | 0.382 | 0.128 | 186.7** | 0.747 | 0.442 | 0.236 | 0.011 | 212.6** |
| **Asia** | Bangladesh | 0.396 | 0.052 | -0.044 | -0.121 | 72.6** | … | … | … | … | … |
| | Hong Kong | 0.725 | 0.445 | 0.144 | -0.106 | 155.7** | 0.801 | 0.539 | 0.257 | 0.013 | 293.0** |
| | India | 0.652 | 0.530 | 0.348 | 0.224 | 348.0** | … | … | … | … | … |
| | Korea, South | 0.776 | 0.537 | 0.299 | 0.109 | 371.6** | … | … | … | … | … |
| | Malaysia | 0.798 | 0.549 | 0.283 | 0.033 | 313.3** | 0.829 | 0.570 | 0.372 | 0.205 | 271.8** |
| | Pakistan | 0.251 | 0.028 | 0.091 | -0.030 | 44.5** | 0.698 | 0.356 | 0.131 | -0.058 | 141.1** |
| | Philippines | 0.717 | 0.495 | 0.275 | 0.084 | 157.8** | 0.733 | 0.388 | 0.095 | -0.169 | 261.9** |
| | Turkey | 0.621 | 0.411 | 0.219 | -0.071 | 231.8** | … | … | … | … | … |
| **East Europe** | Hungary | 0.865 | 0.737 | 0.561 | 0.405 | 384.2** | 0.794 | 0.610 | 0.468 | 0.284 | 300.1** |
| | Lithuania | 0.539 | 0.096 | -0.071 | -0.274 | 42.2** | … | … | … | … | … |
| | Macedonia | 0.351 | -0.036 | -0.108 | -0.029 | 18.8 | 0.435 | 0.265 | -0.028 | -0.014 | 44.2** |
| | Romania | 0.836 | 0.712 | 0.611 | 0.471 | 678.9** | 0.701 | 0.472 | 0.161 | -0.124 | 155.7** |
| | Slovenia | 0.591 | 0.288 | -0.027 | -0.281 | 103.6** | … | … | … | … | … |
| | Slovak Republic | 0.637 | 0.307 | 0.084 | -0.046 | 93.5** | 0.442 | 0.050 | -0.228 | -0.298 | 39.1 |
| **Average** | Developed | 0.844 | 0.630 | 0.400 | 0.146 | … | 0.838 | 0.600 | 0.432 | 0.245 | … |
| | Developing | 0.593 | 0.351 | 0.180 | 0.000 | … | 0.701 | 0.443 | 0.215 | 0.043 | … |

Significance is denoted by * if p<0.05 and ** if p<0.01

**Table 3.3** **Persistence of Prices and Wages**

| Region | Country | CPI | | | | | Nominal Wage | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Lag 1 | Lag 2 | Lag 3 | Lag 4 | Q | Lag 1 | Lag 2 | Lag 3 | Lag 4 | Q |
| **OECD** | US | 0.940 | 0.826 | 0.672 | 0.480 | 846.7** | 0.814 | 0.611 | 0.449 | 0.258 | 343.3** |
| | UK | 0.911 | 0.759 | 0.563 | 0.368 | 707.2** | 0.887 | 0.722 | 0.509 | 0.302 | 649.9** |
| | Japan | 0.912 | 0.781 | 0.610 | 0.384 | 608.0** | 0.946 | 0.819 | 0.639 | 0.434 | 623.8** |
| **Africa** | Côte D'Ivoire | 0.826 | 0.625 | 0.432 | 0.250 | 488.9** | … | … | … | … | … |
| | Malawi | 0.731 | 0.442 | 0.150 | -0.067 | 61.9** | 0.529 | 0.204 | -0.003 | -0.172 | **32.1*** |
| | Nigeria | 0.764 | 0.504 | 0.344 | 0.137 | 298.9** | … | … | … | … | … |
| | Senegal | 0.843 | 0.655 | 0.465 | 0.267 | 501.2** | … | … | … | … | … |
| | South Africa | 0.781 | 0.571 | 0.347 | 0.109 | 447.1** | … | … | … | … | … |
| **North Africa** | Israel | 0.459 | 0.316 | 0.269 | 0.144 | 109.9** | … | … | … | … | … |
| | Jordan | 0.883 | 0.761 | 0.615 | 0.438 | 562.5** | … | … | … | … | … |
| | Morocco | 0.814 | 0.572 | 0.321 | 0.062 | 316.9** | … | … | … | … | … |
| | Tunisia | 0.808 | 0.481 | 0.145 | -0.100 | 125.9** | … | … | … | … | … |
| **Latin America** | Argentina | 0.816 | 0.558 | 0.267 | 0.073 | 114.6** | … | … | … | … | … |
| | Barbados | 0.902 | 0.756 | 0.592 | 0.405 | 774.5** | … | … | … | … | … |
| | Brazil | 0.889 | 0.703 | 0.484 | 0.250 | 150.2** | … | … | … | … | … |
| | Colombia | 0.566 | 0.297 | 0.098 | -0.087 | 195.7** | … | … | … | … | … |
| | Chile | 0.491 | 0.375 | 0.214 | -0.075 | 123.8** | 0.727 | 0.476 | 0.358 | 0.249 | 104.9** |
| | Mexico | 0.829 | 0.671 | 0.521 | 0.384 | 319.4** | 0.467 | 0.549 | 0.386 | 0.178 | 195.4** |
| | Peru | 0.328 | 0.523 | 0.266 | 0.085 | 57.2** | … | … | … | … | … |
| | Trinidad | 0.887 | 0.702 | 0.504 | 0.334 | 665.2** | … | … | … | … | … |
| | Uruguay | 0.418 | -0.091 | -0.096 | -0.114 | 32.8 | … | … | … | … | … |
| **Asia** | Bangladesh | 0.786 | 0.561 | 0.272 | 0.064 | 143.1** | … | … | … | … | … |
| | Hong Kong | 0.889 | 0.765 | 0.623 | 0.473 | 469.2** | 0.781 | 0.620 | 0.413 | 0.224 | 76.8** |
| | India | 0.918 | 0.759 | 0.553 | 0.317 | 980.4** | … | … | … | … | … |
| | Korea, South | 0.913 | 0.762 | 0.583 | 0.377 | 605.9** | … | … | … | … | … |
| | Malaysia | 0.931 | 0.788 | 0.598 | 0.388 | 952.5** | … | … | … | … | … |
| | Pakistan | 0.906 | 0.757 | 0.593 | 0.417 | 778.4** | … | … | … | … | … |
| | Philippines | 0.810 | 0.601 | 0.347 | 0.123 | 403.7** | … | … | … | … | … |
| | Turkey | 0.667 | 0.404 | 0.246 | 0.071 | 86.6** | … | … | … | … | … |
| **East Europe** | Hungary | 0.891 | 0.731 | 0.568 | 0.382 | 358.3** | 0.499 | 0.225 | 0.068 | 0.153 | 104.3** |
| | Lithuania | 0.628 | 0.309 | 0.103 | -0.054 | 40.7* | … | … | … | … | … |
| | Macedonia | 0.731 | 0.442 | 0.150 | -0.067 | 61.9** | 0.529 | 0.204 | -0.003 | -0.172 | **32.1*** |
| | Romania | 0.814 | 0.571 | 0.406 | 0.181 | 178.6** | 0.720 | 0.599 | 0.482 | 0.204 | 181.0** |
| | Slovenia | 0.451 | 0.309 | 0.183 | 0.098 | 50.3** | 0.723 | 0.511 | 0.300 | 0.126 | 89.8** |
| | Slovak Republic | 0.780 | 0.552 | 0.293 | 0.088 | 158.6** | 0.583 | 0.334 | 0.058 | -0.196 | 44.4** |
| **Average** | Developed | 0.921 | 0.789 | 0.615 | 0.411 | … | 0.883 | 0.717 | 0.533 | 0.331 | … |
| | Developing | 0.755 | 0.554 | 0.358 | 0.167 | … | 0.618 | 0.414 | 0.229 | 0.066 | … |

Significance is denoted by * if p<0.05 and ** if p<0.01

### *3.5.2. Volatility*

The volatility analysis measures the magnitude of fluctuations of the variables of interest. From the previous literature, the stylised facts concerning volatility for developing country business cycles are:

- Output volatility is higher than for the developed countries.
- Consumption volatility is higher than output volatility; the opposite finding to that of the developed economies.
- Inflation volatility is similar to that of the developed countries.
- Investment volatility is two to three times higher than output volatility, which is similar to the levels observed in developed countries.
- The real interest rate is significantly more volatile than for the developed countries.
- Private credit is on average less volatile than in the developed countries.
- Net exports are around three times more volatile than output.
- Real exchange rates volatility is similar to that for the developed countries.

These findings are examined here to see whether they are consistent when the sample is expanded to include thirty-two developing countries. Tables 3.4(a), 3.4(b) and 3.4(c) present the results for the volatility of the variables for the individual countries, regional groups and income groups, respectively. Tables 3.5(a), 3.5(b) and 3.5(c) similarly present the results for relative volatility.

Firstly, output is, on average, twice as volatile in the developing countries than in the developed countries. Output is particularly volatile amongst the poorest countries; where, on average, output is 2.5 times more volatile than output in the industrialised economies. This contradicts the finding of Rand and Tarp (2002) who state that output is no more than 20% more volatile in developing countries; however, this discrepancy may result from their choice of HP-filter smoothing parameter.[6] Loayza *et al.* (2007) similarly document that output in developing economies is significantly more volatile than that of the industrialised economies and suggest that the excessive volatility in developing economies arises from three key sources. The first of these suggestions is that developing countries are subject to greater exogenous shocks. The second is that developing economies may be subject to greater domestic shocks arising, for example, from policy mistakes.

[6] Rand and Tarp (2002) document that developing country business cycles are significantly shorter than those of the industrialised countries. Thus, they alter the HP-filer smoothing parameter accordingly. However, as revealed in chapter 2, the developing country cycles are not significantly shorter. Thus, it is not necessary to alter the smoothing parameter.

**Table 3.4(a)** **Volatility (measured as percentage standard deviation)**

| Country | OUTPUT | CPI | CCPI | RW | BM | BMVI | RDC | GEX | GREV | FI | EXP | IMP | TB | TOT | RPC | RGFCF | RMMR | RLR | NEER | REER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| US | 2.9 | 1.3 | 27.6 | 1.1 | 1.6 | 3.4 | 3.1 | 3.2 | 4.5 | 5.8 | 7.2 | 6.1 | 5.7 | 2.7 | 1.5 | 5.2 | 27.3 | 16.5 | 4.9 | 4.5 |
| UK | 2.6 | 2.0 | 82.2 | 1.5 | 8.4 | 8.4 | 6.5 | ... | ... | ... | 5.4 | 6.1 | 4.9 | 2.9 | 1.9 | 4.5 | 38.4 | 14.4 | 4.4 | 5.1 |
| Japan | 3.7 | 1.8 | 75.0 | 1.2 | 1.7 | 3.6 | 2.6 | ... | ... | ... | 7.2 | 11.8 | 8.3 | 6.6 | 1.6 | 3.9 | 47.2 | 7.4 | 7.3 | 7.5 |
| **Africa** | | | | | | | | | | | | | | | | | | | | |
| Côte D'Ivoire | 8.0 | 3.6 | 91.6 | ... | 8.1 | 9.7 | 5.3 | ... | ... | ... | 22.6 | 19.5 | 17.5 | 14.9 | 9.9 | 36.4 | 14.5 | 3.9 | 8.0 | 8.0 |
| Malawi | 6.2 | 8.0 | 52.8 | ... | 7.2 | 8.9 | 14.5 | 20.0 | 9.3 | 21.4 | 14.4 | 13.9 | 18.3 | 12.0 | 8.4 | 20.6 | ... | 11.3 | 13.8 | 12.4 |
| Nigeria | 7.0 | 10.0 | 375.8 | ... | 9.4 | 13.2 | 13.0 | 100.6 | 80.8 | 83.7 | 24.6 | 21.7 | 28.9 | ... | 22.2 | 52.0 | ... | 14.3 | 20.5 | 24.0 |
| South Africa | 3.4 | 1.4 | 33.9 | ... | 3.3 | 3.5 | 3.8 | 6.4 | 7.4 | 7.8 | 11.9 | 15.7 | 13.9 | 3.8 | 2.4 | 6.0 | 21.9 | 13.4 | 8.4 | 8.0 |
| Senegal | 7.4 | 4.7 | 91.4 | ... | 5.4 | 8.2 | 7.7 | ... | ... | ... | 37.7 | 13.3 | 33.6 | ... | 6.0 | 11.0 | 14.7 | 2.5 | ... | ... |
| **North Africa** | | | | | | | | | | | | | | | | | | | | |
| Israel | 4.3 | 26.2 | 56.0 | ... | 49.9 | 22.4 | 9.2 | 89.4 | 90.7 | 14.1 | 6.5 | 10.6 | 11.1 | 3.9 | 20.2 | 19.9 | ... | 37.7 | 19.9 | 7.2 |
| Jordan | 8.2 | 3.7 | 75.4 | ... | 3.3 | 8.5 | 4.9 | 16.3 | 13.1 | 23.1 | 16.3 | 11.8 | 17.0 | ... | 13.3 | 19.7 | ... | 28.9 | 3.3 | 3.2 |
| Morocco | 2.9 | 1.7 | 77.0 | ... | 2.5 | 3.3 | 5.2 | 6.8 | 6.3 | 14.3 | 14.7 | 10.5 | 13.1 | 11.1 | 5.3 | 16.3 | 10.4 | 3.4 | 2.5 | 1.9 |
| Tunisia | 3.5 | 0.7 | 25.6 | ... | 3.0 | 3.5 | 3.5 | 13.8 | 13.0 | 0.4 | 13.9 | 10.3 | 10.4 | ... | 2.4 | 9.0 | 6.6 | 3.4 | 3.4 | ... |
| **Latin America** | | | | | | | | | | | | | | | | | | | | |
| Argentina | 9.6 | 56.6 | 104.7 | ... | 42.2 | 7.9 | 19.2 | 8.3 | 9.0 | 6.9 | 12.5 | 22.9 | 25.4 | 4.2 | 6.0 | 14.5 | ... | 45.2 | ... | ... |
| Barbados | 4.3 | 3.5 | 67.2 | ... | 3.3 | 4.8 | 7.0 | 7.1 | 7.4 | 9.8 | 16.5 | 8.9 | 16.3 | ... | 9.3 | ... | ... | 8.8 | ... | ... |
| Brazil | 3.3 | 59.6 | 63.4 | ... | 56.8 | 9.9 | 11.2 | 61.1 | 11.9 | 12.3 | 10.4 | 13.1 | 14.3 | 15.9 | 6.4 | 8.4 | 101.8 | 11.8 | ... | ... |
| Chile | 8.3 | 7.1 | 56.7 | 0.9 | 5.8 | 5.6 | 6.1 | 94.1 | 97.0 | 1.3 | 17.2 | 17.3 | 2.0 | ... | 7.7 | 23.6 | 22.4 | 14.2 | 6.5 | 2.1 |
| Colombia | 3.1 | 4.8 | 446.4 | ... | 4.0 | 4.6 | 7.4 | 6.7 | 6.4 | 9.6 | 11.0 | 13.1 | 16.5 | 10.2 | 2.3 | 14.4 | 23.2 | 11.5 | 6.8 | 6.8 |
| Mexico | 3.6 | 37.1 | 39.6 | 10.5 | 11.4 | 14.1 | 15.7 | 14.5 | 11.4 | 9.9 | 11.4 | 16.5 | 14.5 | ... | 5.9 | 8.1 | 30.8 | 30.7 | ... | ... |
| Peru | 8.5 | 79.1 | 106.1 | ... | 42.6 | 7.5 | 9.1 | 34.4 | 12.2 | 14.9 | 13.2 | 19.9 | 23.4 | ... | ... | 12.7 | ... | 26.7 | ... | ... |
| Trinidad | 5.9 | 2.4 | 49.3 | ... | 3.9 | 7.6 | 6.0 | ... | ... | ... | 18.7 | 17.9 | 20.1 | 13.4 | 19.0 | 36.8 | ... | 5.3 | 7.0 | 6.9 |
| Uruguay | 5.4 | 47.8 | 41.6 | ... | 41.3 | 12.2 | 13.1 | 20.3 | 12.7 | 12.3 | 16.2 | 17.5 | 19.6 | ... | 13.9 | 19.1 | 35.2 | 26.7 | 14.0 | 9.2 |
| **Asia** | | | | | | | | | | | | | | | | | | | | |
| Bangladesh | 4.4 | 1.5 | 59.7 | ... | 3.6 | 4.2 | 5.0 | ... | ... | ... | 10.8 | 13.9 | 16.0 | ... | 2.5 | 2.8 | ... | 4.2 | ... | ... |
| Hong Kong | 3.8 | 1.9 | 54.3 | 1.7 | 2.4 | 3.4 | 3.5 | 9.4 | 9.3 | 21.3 | 7.0 | 7.9 | 3.1 | 2.3 | 2.5 | 7.4 | 49.6 | 11.6 | 3.9 | 4.0 |
| India | 2.6 | 3.9 | 89.2 | ... | 5.8 | 6.8 | 4.6 | 8.5 | 8.7 | 1.3 | 7.5 | 11.4 | 10.7 | 9.8 | 4.7 | ... | 25.7 | 4.4 | ... | ... |
| Korea, South | 5.1 | 3.4 | 50.5 | ... | 6.9 | 4.9 | 3.0 | 12.2 | 10.0 | 11.5 | 9.4 | 13.7 | 12.8 | 5.3 | 3.7 | 9.7 | 16.5 | 10.9 | ... | ... |
| Malaysia | 6.7 | 2.1 | 60.8 | ... | 3.2 | 7.2 | 4.5 | 10.1 | 13.2 | 12.7 | 10.4 | 11.6 | 8.3 | 9.7 | 7.6 | 23.2 | 4.4 | 13.8 | 5.2 | 5.2 |
| Pakistan | 4.2 | 3.2 | 49.0 | ... | 3.6 | 7.5 | 5.5 | 13.2 | 12.5 | 0.7 | 13.5 | 12.2 | 15.2 | 10.4 | ... | 11.7 | 19.2 | ... | 4.3 | 4.3 |
| Philippines | 18.0 | 7.1 | 78.7 | ... | 3.9 | 19.1 | 9.2 | 11.2 | 20.8 | 10.8 | 11.5 | 11.6 | 12.4 | 6.4 | 8.0 | 12.3 | 19.9 | 14.2 | 6.9 | 6.1 |
| Turkey | 4.0 | 38.8 | 28.2 | ... | 9.6 | 7.5 | 13.7 | 33.3 | 33.5 | 77.1 | 12.3 | 14.1 | 16.8 | 7.0 | 4.6 | 9.6 | 26.8 | ... | ... | ... |
| **East Europe** | | | | | | | | | | | | | | | | | | | | |
| Hungary | 4.7 | 2.6 | 28.3 | 3.1 | 4.5 | 7.7 | 5.8 | 7.9 | 9.8 | 7.6 | 7.1 | 7.3 | 7.6 | 2.8 | 2.6 | 3.2 | ... | 12.1 | 4.5 | 3.9 |
| Lithuania | 14.5 | 23.3 | 69.8 | ... | 10.0 | 13.3 | 12.6 | 7.5 | 8.2 | 5.1 | 10.6 | 11.6 | 6.9 | ... | 5.7 | 11.3 | 26.2 | 20.6 | ... | ... |
| Macedonia | 6.7 | 15.1 | 372.5 | 2.4 | 13.4 | 19.5 | 11.7 | ... | ... | ... | 8.4 | 11.2 | 8.7 | ... | ... | ... | ... | 28.4 | 34.2 | 8.9 |
| Romania | 8.3 | 19.1 | 45.4 | 9.3 | 11.6 | 15.5 | 13.5 | 24.7 | 13.4 | 12.3 | 15.0 | 13.9 | 12.3 | ... | 6.6 | 8.6 | ... | ... | ... | 12.5 |
| Slovak Republic | 2.7 | 2.1 | 42.4 | 2.9 | 2.5 | 3.3 | 13.9 | 6.3 | 7.2 | 5.6 | 10.8 | 9.7 | 7.2 | ... | 2.4 | 10.7 | 15.4 | 14.0 | 4.7 | 3.5 |
| Slovenia | 2.4 | 4.1 | 26.7 | 9.9 | 7.6 | 4.6 | 5.0 | 3.6 | 3.8 | 4.8 | 9.9 | 8.9 | 4.7 | ... | 1.5 | 4.3 | 19.3 | 26.8 | ... | ... |

**Table 3.4(b)** **Summary of Volatility (by Region)**

| Region | OUTPUT | CPI | CCPI | RW | BM | BMVI | RDC | GEX | GREV | FI | EXP | IMP | TB | TOT | RPC | RGFCF | RMMR | RLR | NEER | REER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| US,UK and Japan | 3.1 | 1.7 | 61.6 | 1.2 | 3.9 | 5.1 | 4.1 | 3.2 | 4.5 | 5.8 | 6.6 | 8.0 | 6.3 | 4.1 | 1.7 | 4.5 | 37.6 | 12.7 | 5.5 | 5.7 |
| Africa | 6.4*§* | 5.5 | 129.1 | ... | 6.7 | 8.7 | 8.9 | 42.4 | 32.5 | 37.6 | 22.2*§* | 16.8*§* | 22.4*§* | 10.2 | 9.8 | 25.2 | 17.0 | 9.1 | 12.7 | 13.1 |
| North Africa | 4.7 | 8.1 | 58.5 | ... | 14.7 | 9.4 | 5.7 | 31.6 | 30.8 | 13.0 | 12.8 | 10.8 | 12.9*§* | 7.5 | 10.3 | 16.2*§* | 8.5*§* | 18.3 | 7.3 | 4.1 |
| Latin America | 5.8*§* | 33.1*§* | 108.3 | 5.7 | 23.5*§* | 8.2 | 10.5*§* | 30.8 | 21.0 | 9.6 | 14.1§ | 16.3*§* | 16.9§ | 10.9 | 8.8*§* | 17.2§ | 42.7 | 20.1 | 8.6 | 6.3 |
| Asia | 6.1 | 7.7 | 58.8 | 1.7 | 4.9 | 7.6 | 6.1 | 14.0 | 15.4 | 19.3 | 10.3§ | 12.0 | 11.9*§* | 7.3 | 4.8*§* | 11.0*§* | 23.2 | 9.8 | 5.1 | 4.9 |
| Eastern Europe | 6.6 | 11.0 | 97.5 | 5.5 | 8.3 | 10.6 | 10.4*§* | 10.0 | 8.5 | 7.1 | 10.3*§* | 10.4 | 7.9 | 2.8 | 3.8 | 7.6 | 20.3 | 20.3 | 14.5 | 7.2 |
| All Developing Countries | 6.0§ | 15.2§ | 90.9 | 5.1*§* | 12.2*§* | 8.7 | 8.5*§* | 24.0 | 20.0 | 15.3 | 13.6§ | 13.5 | 14.3§ | 8.4*§* | 7.3§ | 15.3§ | 25.2 | 15.9 | 9.3 | 7.3 |

**Table 3.4(c)** **Summary of Volatility (by Income)**

| Income | OUTPUT | CPI | CCPI | RW | BM | BMVI | RDC | GEX | GREV | FI | EXP | IMP | TB | TOT | RPC | RGFCF | RMMR | RLR | NEER | REER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| High | 3.1 | 1.7 | 61.6 | 1.2 | 3.9 | 5.1 | 4.1 | 3.2 | 4.5 | 5.8 | 6.6 | 8.0 | 6.3 | 4.1 | 1.7 | 4.5 | 37.6 | 12.7 | 5.5 | 5.7 |
| Upper Middle | 5.4§ | 18.1§ | 71.8 | 5.5*§* | 14.7*§* | 8.4 | 9.2*§* | 23.5 | 20.1 | 13.4 | 11.8§ | 13.3 | 12.3§ | 7.1 | 6.8§ | 13.3§ | 30.3 | 18.5 | 8.1 | 6.3 |
| Lower Middle | 5.7 | 17.2 | ... | 2.4 | 11.4 | 8.3 | 6.7 | 16.9 | 11.4 | 10.7 | 13.3§ | 12.6 | 14.6*§* | 10.7 | 7.0 | 13.9 | 12.1*§* | 18.1 | 9.5 | 4.6 |
| Low | 7.6*§* | 5.5 | ... | ... | 6.2 | 10.0 | 8.5 | 35.1 | 29.9 | 29.3 | 18.4*§* | 15.1*§* | 19.6§ | 10.8*§* | 8.8 | 22.5 | 18.7 | 7.8 | 12.3 | 12.6 |

OUTPUT – real manufacturing or industrial production, CPI – consumer price index, CCPI – inflation, RW – real wage, BM – broad money, BMVI – broad money velocity indicator, RDC – real domestic private sector credit, GEX – real government expenditure, GREV – real government revenue, FI – fiscal impulse, EXP – real exports of goods and services, IMP – real imports of goods and services, TB – trade balance, TOT – terms of trade, RPC – real private consumption, RGFCF – real gross fixed capital formation (investment), RMMR – real money market rate, RLR – real lending rate, NEER – nominal effective exchange rate, REER – real effective exchange rate.

Note that numbers in italics indicate that annual rather than quarterly data has been used for that particular result. All of the variables refer to the Hodrick-Prescott filtered cyclical component. Significant differences from the developed country benchmarks (the United States, United Kingdom and Japan) are denoted by *§* ($p < 0.05$) and § ($p < 0.01$).

**Table 3.5(a)** **Relative Volatility**

| Country | CPI | CCPI | RW | BM | BMVI | RDC | GEX | GREV | FI | EXP | IMP | TB | TOT | RPC | RGFCF | RMMR | RLR | NEER | REER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| US | 0.5 | 9.4 | 0.4 | 0.6 | 1.1 | 1.1 | 1.1 | 1.5 | 2.0 | 2.4 | 2.1 | 1.9 | 0.9 | 0.5 | 1.8 | 9.3 | 5.6 | 1.7 | 1.5 |
| UK | 0.8 | 32.2 | 0.6 | 3.3 | 3.3 | 2.5 | ... | ... | ... | 2.1 | 2.4 | 1.9 | 1.1 | 0.7 | 1.8 | 15.0 | 5.6 | 1.7 | 2.0 |
| Japan | 0.5 | 20.1 | 0.3 | 0.5 | 1.0 | 0.7 | ... | ... | ... | 1.9 | 3.2 | 2.2 | 1.8 | 0.4 | 1.1 | 12.7 | 2.0 | 2.0 | 2.0 |
| **Africa** | | | | | | | | | | | | | | | | | | | |
| Côte D'Ivoire | 0.5 | 11.4 | ... | 1.0 | 1.2 | 0.7 | ... | ... | ... | 2.8 | 2.4 | 2.2 | 1.9 | 1.2 | 4.5 | 1.8 | 0.5 | 1.0 | 1.0 |
| Malawi | 1.3 | 8.6 | ... | 1.2 | 1.4 | 2.4 | 3.3 | 1.5 | 3.5 | 2.3 | 2.3 | 3.0 | 2.0 | 1.4 | 3.4 | ... | 1.8 | 2.3 | 2.0 |
| Nigeria | 1.4 | 54.0 | ... | 1.3 | 1.9 | 1.9 | 14.5 | 11.6 | 12.0 | 3.5 | 3.1 | 4.2 | ... | 3.2 | 7.5 | ... | 2.1 | 3.0 | 3.4 |
| South Africa | 0.4 | 10.0 | ... | 1.0 | 1.0 | 1.1 | 1.9 | 2.2 | 2.3 | 3.5 | 4.6 | 4.1 | 1.1 | 0.7 | 1.8 | 6.5 | 3.9 | 2.5 | 2.4 |
| Senegal | 0.6 | 12.4 | ... | 0.7 | 1.1 | 1.1 | ... | ... | ... | 5.1 | 1.8 | 4.5 | ... | 0.8 | 1.5 | 2.0 | 0.3 | ... | ... |
| **North Africa** | | | | | | | | | | | | | | | | | | | |
| Israel | 6.1 | 12.9 | ... | 11.5 | 5.2 | 2.1 | 20.7 | 21.0 | 3.3 | 1.5 | 2.4 | 2.6 | 0.9 | 4.7 | 4.6 | ... | 8.7 | 4.6 | 1.7 |
| Jordan | 0.5 | 9.2 | ... | 0.4 | 1.0 | 0.6 | 2.0 | 1.6 | 2.8 | 2.0 | 1.5 | 2.1 | ... | 1.6 | 2.4 | ... | 3.6 | 0.4 | 0.4 |
| Morocco | 0.6 | 26.9 | ... | 0.9 | 1.2 | 1.8 | 2.4 | 2.2 | 5.0 | 5.1 | 3.7 | 4.6 | 3.9 | 1.8 | 5.7 | 3.7 | 1.2 | 0.9 | 0.7 |
| Tunisia | 0.2 | 7.2 | ... | 0.9 | 1.0 | 1.0 | 3.9 | 3.7 | 0.1 | 3.9 | 2.9 | 3.0 | ... | 0.7 | 2.5 | 1.9 | 1.0 | 1.0 | ... |
| **Latin America** | | | | | | | | | | | | | | | | | | | |
| Argentina | 5.9 | 10.9 | ... | 4.4 | 0.8 | 2.0 | 0.9 | 0.9 | 0.7 | 1.3 | 2.4 | 2.7 | 0.4 | 0.6 | 1.5 | ... | 4.7 | ... | ... |
| Barbados | 0.8 | 15.7 | ... | 0.8 | 1.1 | 1.6 | 1.7 | 1.7 | 2.3 | 3.8 | 2.1 | 3.8 | ... | 2.2 | ... | ... | 2.1 | ... | ... |
| Brazil | 18 | 19.1 | ... | 17.1 | 3.0 | 3.4 | 18.4 | 3.6 | 3.7 | 3.1 | 4.0 | 4.3 | 4.8 | 1.9 | 2.5 | 30.7 | 3.6 | ... | ... |
| Chile | 0.9 | 6.8 | 0.1 | 0.7 | 0.7 | 0.7 | 11.3 | 11.6 | 0.2 | 2.1 | 2.1 | 0.2 | ... | 0.9 | 2.8 | 2.7 | 1.7 | 0.8 | 0.3 |
| Colombia | 1.6 | 145.8 | ... | 1.3 | 1.5 | 2.4 | 2.2 | 2.1 | 3.1 | 3.6 | 4.3 | 5.4 | 3.3 | 0.7 | 4.7 | 7.6 | 3.7 | 2.2 | 2.2 |
| Mexico | 10.3 | 11.0 | 2.9 | 3.2 | 3.9 | 4.4 | 4.0 | 3.2 | 2.8 | 3.2 | 4.6 | 4.0 | ... | 1.6 | 2.3 | 8.6 | 8.5 | ... | ... |
| Peru | 9.3 | 12.5 | ... | 5.0 | 0.9 | 1.1 | 4.0 | 1.4 | 1.7 | 1.6 | 2.3 | 2.8 | ... | ... | 1.5 | ... | 3.1 | ... | ... |
| Trinidad | 0.4 | 8.4 | ... | 0.7 | 1.3 | 1.0 | ... | ... | ... | 3.2 | 3.0 | 3.4 | 2.3 | 3.2 | 6.3 | ... | 0.9 | 1.2 | 1.2 |
| Uruguay | 8.8 | 7.7 | ... | 7.6 | 2.2 | 2.4 | 3.7 | 2.3 | 2.3 | 3.0 | 3.2 | 3.6 | ... | 2.6 | 3.5 | 6.5 | 4.9 | 2.6 | 1.7 |
| **Asia** | | | | | | | | | | | | | | | | | | | |
| Bangladesh | 0.4 | 13.6 | ... | 0.8 | 1.0 | 1.1 | ... | ... | ... | 2.5 | 3.2 | 3.7 | ... | 0.6 | 0.7 | ... | 1.0 | ... | ... |
| Hong Kong | 0.5 | 14.5 | 0.5 | 0.6 | 0.9 | 0.9 | 2.5 | 2.5 | 5.7 | 1.9 | 2.1 | 0.8 | 0.6 | 0.7 | 2.0 | 13.2 | 3.1 | 1.0 | 1.1 |
| India | 1.5 | 34.5 | ... | 2.2 | 2.6 | 1.8 | 3.3 | 3.4 | 0.5 | 2.9 | 4.4 | 4.1 | 3.8 | 1.8 | ... | 9.9 | 1.7 | ... | ... |
| Korea, South | 0.7 | 9.9 | ... | 1.3 | 1.0 | 0.6 | 2.4 | 2.0 | 2.2 | 1.8 | 2.7 | 2.5 | 1.0 | 0.7 | 1.9 | 3.2 | 2.1 | ... | ... |
| Malaysia | 0.3 | 9.0 | ... | 0.5 | 1.1 | 0.7 | 1.5 | 2.0 | 1.9 | 1.5 | 1.7 | 1.2 | 1.4 | 1.1 | 3.5 | 0.7 | 2.1 | 0.8 | 0.8 |
| Pakistan | 0.8 | 11.7 | ... | 0.9 | 1.8 | 1.3 | 3.2 | 3.0 | 0.2 | 3.2 | 2.9 | 3.6 | 2.5 | ... | 2.8 | 4.6 | ... | 1.0 | 1.0 |
| Philippines | 0.4 | 4.4 | ... | 0.2 | 1.1 | 0.5 | 0.6 | 1.2 | 0.6 | 0.6 | 0.7 | 0.7 | 0.4 | 0.4 | 0.7 | 1.1 | 0.8 | 0.4 | 0.3 |
| Turkey | 9.7 | 7.0 | ... | 2.4 | 1.9 | 3.4 | 8.3 | 8.4 | 19.2 | 3.1 | 3.5 | 4.2 | 1.7 | 1.1 | 2.4 | 6.7 | ... | ... | ... |
| **East Europe** | | | | | | | | | | | | | | | | | | | |
| Hungary | 0.6 | 6.0 | 0.7 | 1.0 | 1.6 | 1.2 | 1.7 | 2.1 | 1.6 | 1.5 | 1.6 | 1.6 | 0.6 | 0.6 | 0.7 | ... | 2.6 | 1.0 | 0.8 |
| Lithuania | 1.6 | 4.8 | ... | 0.7 | 0.9 | 0.9 | 0.5 | 0.6 | 0.4 | 0.7 | 0.8 | 0.5 | ... | 0.4 | 0.8 | 1.8 | 1.4 | ... | ... |
| Macedonia | 2.2 | 55.4 | 0.4 | 2.0 | 2.9 | 1.7 | ... | ... | ... | 1.3 | 1.7 | 1.3 | ... | ... | ... | ... | 4.2 | 5.1 | 1.3 |
| Romania | 2.3 | 5.5 | 1.1 | 1.4 | 1.9 | 1.6 | 3.0 | 1.6 | 1.5 | 1.8 | 1.7 | 1.5 | ... | 0.8 | 1.0 | ... | ... | ... | 1.5 |
| Slovak Republic | 0.8 | 15.6 | 1.1 | 0.9 | 1.2 | 5.1 | 2.3 | 2.6 | 2.1 | 4.0 | 3.6 | 2.6 | ... | 0.9 | 3.9 | 5.6 | 5.1 | 1.7 | 1.3 |
| Slovenia | 1.7 | 11.1 | 4.1 | 3.2 | 1.9 | 2.1 | 1.5 | 1.6 | 2.0 | 4.1 | 3.7 | 2.0 | ... | 0.6 | 1.8 | 8.0 | 11.1 | ... | ... |

**Table 3.5(b)** **Summary of Relative Volatility (by Region)**

| Region | CPI | CCPI | RW | BM | BMVI | RDC | GEX | GREV | FI | EXP | IMP | TB | TOT | RPC | RGFCF | RMMR | RLR | NEER | REER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| US,UK and Japan | 0.6 | 20.6 | 0.4 | 1.5 | 1.8 | 1.4 | 1.1 | 1.5 | 2.0 | 2.1 | 2.6 | 2.0 | 1.3 | 0.5 | 1.6 | 12.3 | 4.4 | 1.8 | 1.8 |
| Africa | 0.8 | 19.3 | ... | 1.0 | 1.3 | 1.4 | 6.6 | 5.1 | 5.9 | 3.4[ʃ] | 2.8 | 3.6[ʃ] | 1.7 | 1.5 | 3.7 | 3.4[ʃ] | 1.7 | 2.2 | 2.2 |
| North Africa | 1.9 | 14.1 | ... | 3.4 | 2.1 | 1.4 | 7.3 | 7.1 | 2.8 | 3.1 | 2.6 | 3.1 | 2.4 | 2.2 | 3.8 | 2.8[ʃ] | 3.6 | 1.7 | 0.9 |
| Latin America | 6.2[ʃ] | 26.4 | 1.5 | 4.5 | 1.7 | 2.1 | 5.8 | 3.4 | 2.1 | 2.8 | 3.1 | 3.4[ʃ] | 2.7 | 1.7[§] | 3.1[ʃ] | 11.2 | 3.7 | 1.7 | 1.4 |
| Asia | 1.8 | 13.1 | 0.5 | 1.1 | 1.4 | 1.3 | 3.1 | 3.2 | 4.3 | 2.2 | 2.7 | 2.6 | 1.6 | 0.9 | 2.0 | 5.6[ʃ] | 1.8 | 0.8[§] | 0.8[§] |
| Eastern Europe | 1.5[ʃ] | 16.4 | 1.5 | 1.5 | 1.7 | 2.1 | 1.8 | 1.7 | 1.5 | 2.2 | 2.2 | 1.6 | 0.6 | 0.7 | 1.6 | 5.1[ʃ] | 4.9 | 2.6 | 1.2[ʃ] |
| All Developing Countries | 2.7[§] | 18.7 | 1.1 | 2.3 | 1.6 | 1.7 | 4.5 | 3.7 | 3.1 | 2.6 | 2.7 | 2.8[§] | 1.8 | 1.3[§] | 2.7[§] | 7.1[ʃ] | 3.3 | 1.8 | 1.4 |

**Table 3.5(c)** **Summary of Relative Volatility (by Income)**

| Income | CPI | CCPI | RW | BM | BMVI | RDC | GEX | GREV | FI | EXP | IMP | TB | TOT | RPC | RGFCF | RMMR | RLR | NEER | REER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| High | 0.6 | 20.5 | 0.4 | 1.4 | 1.8 | 1.4 | 1.1 | 1.5 | 2.0 | 2.2 | 2.5 | 2.0 | 1.3 | 0.5 | 1.5 | 12.3 | 4.4 | 1.8 | 1.8 |
| Upper Middle | 3.7[§] | 17.5 | 1.5 | 3.2 | 1.7 | 2.0 | 4.9 | 4.0 | 3.2 | 2.6 | 2.8 | 2.7 | 1.7 | 1.4[§] | 2.7[ʃ] | 7.8 | 4.1 | 1.8 | 1.3[ʃ] |
| Lower Middle | 2.3 | ... | 0.4 | 1.7 | 1.5 | 1.3 | 3.1 | 2.4 | 2.0 | 2.8 | 2.5 | 2.9 | 3.2 | 1.4 | 3.0 | 3.4[ʃ] | 2.6 | 1.7 | 0.9[§] |
| Low | 0.9 | ... | ... | 1.1 | 1.5 | 1.3 | 5.4 | 4.4 | 4.1 | 2.8[§] | 2.5 | 3.2[§] | 2.0 | 1.3 | 3.0 | 3.7[ʃ] | 1.2 | 1.6 | 1.7 |

For notes see Table 3.4(c)

The third, and final, is that external shocks have greater effects on volatility because the developing economies do not possess either the financial markets necessary to diversify risks or the ability to perform stabilising macroeconomic policy. This final point has significant implications for the welfare of the economy. Hnatkovska and Loayza (2005) document a significant negative relationship between economic growth and output volatility, which is exacerbated by underdeveloped financial markets and institutions. Thus, under these conditions, external shocks have a greater effect on volatility and consequently lower economic growth. In particular, it is estimated in Hnatkovska and Loayza (2005) that a one-standard-deviation increase in volatility would reduce the economy's growth rate by 1.3%.

Returning to Tables 3.4(a) and 3.4(b), it is evident that the African and Eastern European countries exhibit the highest average volatilities. However, the Eastern European average is skewed by the exceedingly high output volatility of 14.5% observed in Lithuania, with all the other Eastern European countries exhibiting much lower output volatility. Another country with exceedingly high output volatility is the Philippines; at 18% this is three times greater than the developing country average and six times greater than the developed country average. This high output volatility was similarly observed in the amplitude analysis in Chapter 2, where it was observed that the Philippines experience, on average, a 69% increase in output during business cycle expansions and a 50% reduction in output during recessions, compared to a 6.4% rise during expansions and a 2% decline during recessions in the US.[7] Given the previous analysis, the excessive volatility in the Philippines may go some way to explaining the country's relatively poor growth rates, in relation to the other Asian economies.[8]

Secondly, from Tables 3.5(a),(b) and (c), it is apparent that consumption in the developed countries (the US, the UK and Japan) is on average 50% less volatile than output, whereas in the developing countries consumption is, on average, 30% more volatile than output; however, there is much regional variation. Consumption volatility is highest in North Africa, and in particular in Israel where it is almost five times more volatile than output. Conversely, on average consumption volatility is slightly lower than output volatility in the Asian and Eastern European regions. The fact that consumption volatility is higher than output volatility in Africa, North Africa and Latin America points to a lack of consumption smoothing over the course of the business cycle in these regions. Thus, large welfare gains

[7] See Table 2.6 in Chapter 2.
[8] For the period 1980 to 2005, the average growth rates of GDP and GDP per capita in the Philippines were 2.86% and 0.59%, respectively, compared with regional averages of 5.05% for GDP and 3.13% for GDP per capita. See Table 2.2 for more information.

may be possible through reductions in consumption volatility in these regions (Loayza *et al.*, 2007).

Thirdly, government revenue and expenditure are significantly more volatile in the developing countries, than in the developed countries. On average government expenditure is four and a half times more volatile than output and government revenue is almost four times more volatile than output. This situation is worst in North Africa, where both government expenditure and revenue are more than seven times more volatile than output. The observed high volatility in these developing countries suggests that the government may actually aggravate business cycle fluctuation, rather than help to smooth them.

Fourthly, from the existing stylised facts, it is expected that investment volatility in the developing countries should be two to three times higher than output volatility and of a similar level to that in the developed countries. However, whilst the East European countries have similar investment volatilities to the US, UK and Japan, the other developing countries have significantly higher investment volatilities. In particular, Africa and North Africa where investment volatility is almost four times greater than output volatility; most notably, Nigeria where investment is seven and a half times more volatile than output. However, when aggregating across income groupings the observed relative volatility of investment is consistent with that expected for the developing economies.

Fifthly, considering prices and inflation it is obvious that the Latin American countries exhibit the highest volatilities, with prices more than six times more volatile than output and inflation more than twenty-six times more volatile than output. Prices in the developed countries and in Africa are less volatile than output, whilst prices in the other regions are around 50% more volatile than output. Referring now to inflation, with the exception of the Latin American countries, on average the developing countries exhibit significantly less inflation volatility than the developed countries; however, this result is skewed by the high inflation volatilities in the UK and Japan.

Sixthly the money-related variables are examined. Neumeyer and Perri (2005) suggest that the real interest rate is significantly more volatile for developing economies than for developed countries. Examination of the absolute volatilities in Table 3.4(b) reveals that whilst for the real lending rate the North African, Latin American and Eastern European countries have higher volatilities than the developed countries. In the case of the real money market rate, only the Latin American countries have higher volatilities than the developed countries. Furthermore, examination of the relative volatilities in Table 3.5(a) reveals that, with just one exception, the relative volatility of real interest rates is lower in the developing countries than in the developed countries. For all countries, the volatility of the real interest rate is significantly greater than the volatility of output. The relative volatilities of both broad money and the broad money velocity indicator are similar amongst the developing and developed countries, only North Africa and Latin America have significantly greater relative volatilities of broad money. However, in developing countries it is important to additionally examine real domestic private sector credit. This is because, as discussed in Agénor *et al.* (2000), where equity markets are weakly capitalised private sector credit will have a significant influence on economic activity. Tables 3.5(a), (b) and (c) show the volatility of real domestic credit to be of a similar level to that of the developed countries, with slightly higher volatility in Latin America and Eastern Europe. This contradicts the finding of Rand and Tarp (2002) that private sector credit is on average less volatile than in the developed countries.

Finally, the trade-related variables are considered. Firstly, the trade balance is examined. From the existing stylised facts, the expectation is that the trade balance should be around three times more volatile than output, and the results in Tables 3.5(a), (b) and (c) are consistent with this. Additionally, the relative volatility of the trade balance in the developing countries is significantly greater than that of the developed countries. The only exceptions are the Eastern European countries, where the trade balance is, on average, just 0.6 times more volatile than output. The findings for the imports, exports and the terms of trade are fairly similar to those for the trade balance.

The volatility of the nominal and real effective exchange rates for the developing countries are similar to those for the developed countries, which is consistent with the finding of Rand and Tarp (2002). However, the Asian countries display significantly lower exchange rate volatility and moreover for these countries both the nominal and real exchange rates are less volatile than output. This is a significant finding, because one of the key features of international business cycles that has interested macroeconomists in recent years is the volatility and persistence of real exchange rates. Flood and Rose (1995) suggest that whilst the choice of exchange rate regime affects the volatility of the exchange rate, the volatility of output is stable across regimes. Therefore, where economies maintain a fixed exchange rate regime, exchange rates will be less volatile than output. This is a consistent with the Asian experience for Hong Kong, Malaysia and Pakistan; all of which have held fixed, or pegged, exchange rates for significant durations of the sample period. However, the Philippines, which has the lowest relative volatility, has held a free-float since 1983. Nonetheless, the low relative volatility can perhaps be explained simply by the extremely high output volatility experienced in the Philippines. Compared to the other Asian economies, the Philippines has the highest absolute volatility of exchange rates (6.1%), resulting from its free-float, however in relation to its output volatility of 18.0%, the relative volatility of the exchange rates is extremely low.

### *3.5.3. Cross-Correlations with Real Domestic Output*

The degree of co-movement of the variables of interest ($y_t$) with real industrial (or manufacturing) production ($x_t$) is measured by the magnitude of the correlation coefficient $\rho(j), j \in \{0, \pm1, \pm2, ...\}$. Following the reasoning of Agénor *et al.* (2000), the series is considered to be strongly contemporaneously correlated if $0.22 \leq |\rho(j)| < 1$, weakly contemporaneously correlated if $0.11 \leq |\rho(j)| < 0.22$ and contemporaneously uncorrelated with the cycle if $0 \leq |\rho(j)| < 0.11$. These values are selected because, given the average number of observations per country, the average standard error of the correlation coefficients, computed under the null hypothesis of no correlation, is 0.11.

Tables 3.6(a), 3.6(b) and 3.6(c) report the contemporaneous correlations for all the variables with output. Tables reporting the cross-correlations between domestic output and each of the variables with leads and lags are available in Appendix B.

#### *(a) Industrial Country Business Cycles*

The first relationship considered is whether output fluctuations in developing countries are positively correlated with economic activity in the main industrialised countries, as proxied by world output and world real interest rate. In particular, Agénor *et al.* (2000) suggest that relationship with the world real interest rate could be important because it is likely to effect economic activity in the developing country by both affecting domestic interest rates and by reflecting credit conditions in international capital markets.

From Table 3.6(a), it can be seen that there is a clear relationship, the contemporaneous correlation of domestic output with world output is positive for all the developing countries, with the sole exception of Jordan ($\rho(0) = -0.035$). The majority of countries peak at $j = 0$, or at least by $j = 4$, suggesting that output fluctuations in the industrialised countries are transmitted fairly rapidly to developing countries.

**Table 3.6(a) Contemporaneous Correlation with Real Domestic Output**

| Country | CPI | CCPI | RW | BM | BMVI | RDC | GEX | GREV | FI | EXP | IMP | TB | TOT | RPC | RGFCF | RMMR | RLR | NEER | REER | WO | WIR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| US | -0.47* | 0.27* | 0.41* | 0.03 | -0.69* | 0.77* | -0.41* | 0.59* | -0.70* | 0.25* | 0.58* | -0.31* | -0.25* | 0.68* | 0.87* | 0.58* | 0.58* | -0.16 | -0.14 | 0.78* | 0.55* |
| UK | -0.51* | 0.23* | 0.26* | 0.10 | -0.06 | 0.23* | -0.54* | ... | ... | 0.23* | 0.47* | -0.34* | -0.17 | 0.52* | 0.51* | 0.12 | 0.21 | -0.23* | -0.34* | 0.61* | 0.44* |
| Japan | -0.35* | 0.43* | 0.53* | 0.39* | -0.68* | 0.36* | 0.25* | ... | ... | 0.42* | 0.62* | -0.55* | -0.36* | 0.37* | 0.76* | 0.31* | 0.24* | -0.25* | -0.24* | 0.82* | 0.35* |
| **Africa** | | | | | | | | | | | | | | | | | | | | | |
| Côte D'Ivoire | 0.17 | 0.08 | ... | 0.19 | -0.74* | -0.14 | ... | ... | ... | -0.19 | 0.09 | -0.21 | 0.19 | ... | ... | 0.10 | 0.23* | -0.06 | -0.17 | 0.01 | 0.24* |
| Malawi | -0.24* | -0.41* | ... | 0.01 | -0.53* | 0.25* | 0.09 | 0.03 | 0.08 | 0.13 | 0.26* | -0.10 | 0.06 | ... | ... | ... | -0.26* | 0.43* | 0.36* | 0.13 | -0.02 |
| Nigeria | -0.26* | -0.22* | ... | -0.31* | -0.53* | 0.11 | -0.55* | 0.09 | -0.25* | 0.38* | -0.04 | 0.33* | ... | ... | ... | ... | 0.38* | -0.09 | -0.22* | 0.30* | 0.11 |
| South Africa | -0.12 | 0.12 | ... | 0.47* | -0.54* | 0.39* | 0.04 | -0.43* | -0.28* | 0.32* | 0.71* | -0.56* | 0.22* | 0.56* | 0.63* | 0.15 | 0.13 | 0.01 | -0.02 | 0.17 | 0.18 |
| Senegal | 0.12 | 0.02 | ... | 0.07 | -0.87* | -0.18 | ... | ... | ... | ... | ... | ... | ... | ... | ... | 0.57* | 0.45* | ... | ... | 0.50* | -0.40* |
| **North Africa** | | | | | | | | | | | | | | | | | | | | | |
| Israel | 0.19 | -0.43* | ... | 0.19 | -0.49* | 0.04 | ... | ... | ... | 0.14 | 0.35* | -0.25* | 0.13 | 0.25* | 0.37* | ... | -0.02 | -0.23* | -0.12 | 0.04 | 0.24* |
| Jordan | -0.16 | -0.14 | ... | -0.04 | -0.91* | -0.06 | -0.16 | -0.70* | -0.28* | 0.07 | -0.03 | 0.09 | ... | ... | ... | 0.17 | 0.35* | ... | ... | -0.04 | 0.73* |
| Morocco | -0.24* | -0.07 | ... | 0.10 | -0.66* | -0.06 | 0.29* | 0.24* | 0.13 | 0.13 | -0.06 | 0.21 | -0.14 | ... | ... | 0.18 | 0.03 | -0.09 | -0.29* | 0.20 | 0.08 |
| Tunisia | -0.15 | -0.43* | ... | 0.34* | -0.53* | 0.30* | ... | ... | ... | 0.31* | 0.08 | 0.32* | ... | ... | ... | 0.43* | ... | -0.09 | -0.13 | 0.34* | 0.18 |
| **Latin America** | | | | | | | | | | | | | | | | | | | | | |
| Argentina | 0.60* | 0.24* | ... | 0.60* | -0.79* | 0.18 | 0.74* | 0.71* | -0.39* | 0.39* | 0.74* | -0.69* | 0.28* | 0.71* | 0.90* | ... | -0.80* | ... | ... | 0.61* | 0.20 |
| Barbados | -0.44* | -0.12 | ... | 0.05 | -0.69* | 0.35* | 0.20 | 0.20 | 0.02 | 0.07 | 0.38* | -0.15 | ... | ... | ... | ... | 0.20 | ... | ... | 0.45* | 0.28* |
| Brazil | 0.42* | 0.40* | ... | 0.37* | -0.59* | 0.28* | 0.51* | 0.53* | -0.14 | 0.16 | 0.58* | -0.52* | -0.32* | 0.49* | 0.64* | -0.76* | -0.74* | ... | ... | 0.56* | -0.07 |
| Colombia | -0.30* | 0.23* | ... | 0.07 | -0.48* | 0.09 | 0.35* | 0.17 | 0.12 | 0.20 | 0.40* | -0.19 | 0.17 | 0.64* | 0.67* | 0.30* | 0.27* | 0.26* | 0.29* | 0.28* | 0.04 |
| Chile | -0.01 | -0.13 | -0.05 | 0.45* | -0.52* | -0.14 | ... | ... | ... | 0.58* | -0.20 | 0.52* | ... | 0.22* | -0.95* | -0.32* | -0.22* | 0.11 | 1.00* | 0.60* | 0.31* |
| Mexico | -0.33* | -0.52* | 0.28* | 0.05 | 0.02 | 0.47* | -0.11 | -0.31* | -0.09 | 0.35* | 0.77* | -0.61* | ... | 0.56* | 0.80* | -0.47* | -0.48* | ... | ... | 0.33* | 0.13 |
| Peru | -0.39* | -0.05 | ... | -0.46* | -0.68* | 0.17 | -0.23* | 0.15 | -0.10 | -0.04 | 0.67* | -0.55* | ... | ... | 0.77* | ... | -0.34* | ... | ... | 0.26* | 0.13 |
| Trinidad | -0.22* | -0.15 | ... | -0.19 | -0.83* | 0.02 | ... | ... | ... | 0.02 | 0.01 | 0.02 | -0.09 | ... | ... | ... | -0.07 | -0.13 | -0.23* | 0.17 | 0.11 |
| Uruguay | -0.14 | -0.04 | ... | 0.36* | -0.40* | -0.20 | 0.36* | -0.37* | -0.21 | 0.50* | 0.66* | -0.27* | ... | ... | ... | 0.31* | -0.36* | -0.27* | -0.12 | 0.33* | 0.25* |
| **Asia** | | | | | | | | | | | | | | | | | | | | | |
| Bangladesh | 0.06 | 0.12 | ... | 0.26* | -0.59* | 0.33* | ... | ... | ... | -0.01 | 0.31* | -0.27* | ... | ... | ... | ... | 0.06 | ... | ... | 0.07 | -0.17 |
| Hong Kong | 0.07 | 0.28* | 0.41* | 0.69* | -0.61* | 0.29* | -0.21 | -0.58* | -0.32* | 0.64* | 0.66* | -0.32* | -0.56* | 0.63* | 0.62* | 0.11 | 0.33* | 0.09 | 0.07 | 0.22* | 0.35* |
| India | -0.40* | -0.10 | ... | -0.02 | -0.16 | 0.44* | ... | ... | ... | 0.06 | -0.45* | 0.20 | 0.32* | ... | ... | 0.42* | 0.04 | ... | ... | 0.54* | 0.47* |
| Korea, South | -0.48* | -0.25* | ... | 0.33* | -0.44* | 0.19 | -0.04 | -0.39* | -0.28* | 0.35* | 0.53* | -0.32* | 0.36* | 0.32* | 0.47* | -0.30* | -0.36* | ... | ... | 0.21 | 0.24* |
| Malaysia | -0.07 | 0.15 | ... | 0.02 | -0.91* | -0.11 | -0.21 | -0.68* | -0.32* | 0.55* | 0.26* | -0.03 | 0.53* | -0.32* | -0.06 | 0.81* | 0.75* | 0.36* | 0.32* | 0.43* | 0.18 |
| Philippines | 0.05 | 0.13 | ... | 0.18 | -0.93* | 0.26* | -0.03 | -0.89* | -0.20 | 0.10 | 0.59* | -0.15 | 0.45* | 0.02 | 0.20 | 0.23* | 0.08 | 0.28* | 0.35* | 0.09 | -0.24* |
| Pakistan | 0.13 | 0.24* | ... | -0.07 | -0.57* | 0.00 | ... | ... | ... | 0.24* | 0.23* | 0.03 | 0.05 | ... | ... | 0.00 | ... | -0.01 | 0.00 | 0.15 | -0.02 |
| Turkey | -0.13 | -0.26* | ... | -0.37* | -0.78* | 0.65* | ... | ... | ... | 0.11 | 0.64* | -0.55* | 0.08 | 0.67* | 0.79* | -0.22* | ... | ... | ... | 0.16 | -0.10 |
| **East Europe** | | | | | | | | | | | | | | | | | | | | | |
| Hungary | -0.59* | 0.18 | 0.30* | -0.57* | -0.84* | 0.42* | -0.63* | -0.87* | -0.61* | 0.12 | 0.00 | 0.11 | 0.36* | -0.30* | 0.01 | ... | -0.01 | -0.34* | -0.69* | 0.35* | 0.48* |
| Lithuania | -0.10 | 0.03 | ... | 0.41* | -0.94* | 0.24* | 0.44* | -0.90* | 0.65* | -0.07 | -0.01 | -0.11 | 0.10 | 0.29* | ... | -0.12 | -0.02 | ... | ... | 0.20 | 0.23* |
| Macedonia | -0.25* | 0.46* | 0.24* | 0.07 | -0.35* | 0.21 | ... | ... | ... | 0.43* | 0.27* | 0.07 | ... | ... | ... | ... | 0.09 | -0.15 | -0.22* | 0.12 | -0.20 |
| Romania | -0.62* | -0.28* | 0.56* | -0.31* | -0.86* | -0.42* | -0.02 | 0.10 | 0.44* | 0.58* | 0.64* | 0.01 | ... | -0.11 | 0.85* | ... | ... | ... | 0.29* | 0.23* | 0.14 |
| Slovenia | 0.58* | 0.56* | 0.34* | 0.35* | -0.56* | -0.27* | 0.27* | -0.64* | 0.17 | 0.22 | 0.09 | 0.17 | ... | -0.59* | -0.63* | -0.04 | 0.25* | ... | ... | 0.36* | 0.12 |
| Slovak Republic | 0.13 | -0.46* | 0.00 | 0.38* | -0.59* | -0.46* | ... | ... | ... | 0.50* | 0.55* | 0.08 | ... | -0.10 | 0.04 | 0.22* | 0.45* | 0.02 | -0.11 | 0.11 | -0.14 |

**Table 3.6(b)** **Summary of Contemporaneous Correlations with Real Domestic Output (by Region)**

| | CPI | CCPI | RW | BM | BMVI | RDC | GEX | GREV | FI | EXP | IMP | TB | TOT | RPC | RGFCF | RMMR | RLR | NEER | REER | WO | WIR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| US, UK and Japan | -0.44* | 0.31* | 0.40* | 0.16 | -0.48* | 0.46* | -0.23* | 0.59* | -0.70* | 0.30* | 0.56* | -0.40* | -0.26* | 0.52* | 0.71* | 0.34* | 0.34* | -0.21 | -0.24* | 0.73* | 0.45* |
| Africa | -0.07§ | -0.08 | ... | 0.08 | -0.64* | 0.09 | -0.14 | -0.10 | -0.15 | 0.16 | 0.26* | -0.13 | 0.16§ | 0.56* | 0.63* | 0.28* | 0.18 | 0.07 | -0.01 | 0.22*§ | 0.02§ |
| North Africa | -0.09§ | -0.27*§ | ... | 0.15 | -0.65* | 0.06 | 0.06 | -0.23* | -0.08 | 0.16 | 0.08§ | 0.09§ | 0.00 | 0.25* | 0.37* | 0.26* | 0.12 | -0.13 | -0.18 | 0.14§ | 0.31* |
| Latin America | -0.09§ | -0.02 | 0.11 | 0.14 | -0.55* | 0.14 | 0.26* | 0.15 | -0.11 | 0.25* | 0.44* | -0.27* | 0.01 | 0.53* | 0.47* | -0.19 | -0.28*§ | -0.01 | 0.24* | 0.40*§ | 0.15§ |
| Asia | -0.10§ | 0.04 | 0.41* | 0.13 | -0.62* | 0.26* | -0.12 | -0.64* | -0.28* | 0.25* | 0.35* | -0.17 | 0.18 | 0.26* | 0.40* | 0.15 | 0.15 | 0.18§ | 0.18§ | 0.24*§ | 0.09§ |
| Eastern Europe | -0.14 | 0.08 | 0.29* | 0.06 | -0.69* | -0.05 | 0.01 | -0.58* | 0.16 | 0.30* | 0.26* | 0.06§ | 0.23* | -0.16§ | 0.06 | 0.02 | 0.15 | -0.16 | -0.18 | 0.23*§ | 0.11§ |
| All Developing Countries | -0.10§ | -0.03 | 0.26* | 0.11 | -0.62* | 0.11 | 0.05 | -0.23* | -0.09 | 0.24* | 0.31* | -0.12§ | 0.12§ | 0.23* | 0.36* | 0.08 | 0.01 | 0.01§ | 0.02§ | 0.27*§ | 0.13§ |

**Table 3.6(c)** **Summary of Contemporaneous Correlations with Real Domestic Output (by Income)**

| | CPI | CCPI | RW | BM | BMVI | RDC | GEX | GREV | FI | EXP | IMP | TB | TOT | RPC | RGFCF | RMMR | RLR | NEER | REER | WO | WIR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| High | -0.44* | 0.31* | 0.40* | 0.16 | -0.48* | 0.46* | -0.23* | 0.59* | -0.70* | 0.30* | 0.56* | -0.40* | -0.26* | 0.52* | 0.71* | 0.34* | 0.34* | -0.21 | -0.24* | 0.73* | 0.45* |
| Upper Middle | -0.08§ | -0.04 | 0.26* | 0.16 | -0.57* | 0.06 | 0.15 | -0.21 | -0.10 | 0.27* | 0.39* | -0.11§ | 0.04 | 0.22* | 0.34* | 0.01 | -0.04 | 0.00 | 0.07 | 0.30*§ | 0.17§ |
| Lower Middle | -0.19§ | -0.02 | 0.24* | 0.03 | -0.68* | 0.14 | -0.03 | -0.30* | -0.11 | 0.17 | 0.25* | 0.00§ | 0.15 | 0.02 | 0.49* | 0.25* | 0.04 | -0.01 | -0.07 | 0.16§ | 0.12 |
| Low | -0.06§ | -0.04 | ... | 0.02 | -0.57* | 0.12 | -0.23* | 0.06 | -0.09 | 0.10 | 0.07 | 0.05 | 0.15§ | ... | ... | 0.27* | 0.15 | 0.07§ | -0.01 | 0.24*§ | 0.03§ |

WO – world real output, WIR – world real interest rate. For other variable names, see Table 3.4(c).

Note that numbers marked in bold indicate weak contemporaneous correlation and numbers marked in bold with a * indicate strong contemporaneous correlation. All of the variables refer to the Hodrick-Prescott filtered cyclical component. Significant differences from the developed country benchmarks (the United States, United Kingdom and Japan) are denoted by *§* ($p < 0.05$) and **§** ($p < 0.01$).

For world real interest rate, Table 3.6(a) shows a slightly less clear relationship. The contemporaneous correlation between domestic output and the world real interest rate is positive for most countries; however, it is negative for five countries and there is no significant relationship for six countries. The majority peak at j = 0, suggesting rapid transmission, but again there is more variation than for world output. Where there is a positive correlation, this may reflect the positive spill over effect of pro-cyclical interest rates in the industrialised countries on the developing country's output.

Examination of Table 3.6(c) would seem to suggest that contemporaneous correlation between domestic output and the world real interest rate increases as economies become relatively more developed. This may reflect the fact that as economies develop, their domestic capital markets become more sophisticated and thus are more likely to be influenced by changes in international credit conditions.

Overall, findings for both of world output and world real interest rate are consistent with Agénor *et al.* (2000).

*(b) Prices, Inflation and Real Wages*

For the industrialised countries, there is a clear pattern of countercyclical prices and a substantial literature documenting this. For developing countries, however this pattern is not nearly so clear. Rand and Tarp (2002) report a large negative association between CPI and GDP, whilst Agénor *et al.* (2000) find a generally negative pattern with a few significant positive relationships in Chile, Mexico, the Philippines and Uruguay.

Table 3.6(a) reports significant countercyclical prices for the US, the UK and Japan, and similarly prices are countercyclical in eighteen of the developing countries, and strongly so in thirteen of these. However, prices are acyclical in six of the developing countries and procyclical in eight. In particular, Argentina, Brazil and the Slovak Republic have strongly procyclical prices. Thus, this supports the findings of Agénor *et al.* (2000) that there is not a consistent negative relationship for the developing countries.

There is a similar lack of consistency in the relationship between output and inflation in the developing countries. Looking at Table 3.6(a), inflation is strongly procyclical in the industrialised countries and in sixteen of the developing countries, whilst it is countercyclical in the remaining seventeen developing countries. Looking closer, however, there does appear to be a relationship between the CPI correlations and the inflation correlations for the developing countries; there is a tendency for those developing countries with countercyclical CPI to also exhibit countercyclical inflation. This is a significant difference from the pattern of procyclical inflation and countercyclical prices in the industrialised countries.

The identification of the pattern of price and inflation correlations with output is necessary for the correct classification of demand and supply shocks. Chadha and Prasad (1994), amongst others, identify that if fluctuations in output are attributable to demand shocks, then both prices and inflation should be procyclical. Conversely, if such fluctuations are attributable to supply shocks, both prices and inflation should be countercyclical. For many of the countries examined here, including the developed countries, it is therefore difficult to clearly identify whether business cycle fluctuations are driven by supply or demand shocks. However, for several of the developing countries there is a clear pattern of both countercyclical prices and inflation.[9] Consequently, it is plausible that business cycles in these countries are driven by supply shocks. Conversely, both prices and inflation are strongly procyclical in Argentina, Brazil and Slovenia, suggesting that business cycle fluctuations in these countries are attributable to demand shocks.

The correlation between output and real wages shows much more consistency. In almost all the countries, both developing and developed, the contemporaneous correlation is positive suggesting procyclical real wages. The only exceptions in this case are Chile and the Slovak Republic, where real wages are acyclical. As discussed in Agénor *et al.* (2000), the identification of whether real wages are procyclical or countercyclical has important implications for the choice of theoretical model to represent developing country business cycles. The procyclical wages in this case suggest the application of either a New Keynesian model with imperfect competition and countercyclical mark-ups, or a real business cycle model.

*(c) Consumption and Investment*

Real private consumption is strongly procyclical for the OECD countries and for the majority of the developing countries in the sample. However, real private consumption is countercyclical for four developing countries, three of which are East European countries. With the exception of the East European countries, this is consistent with Rand and Tarp (2002) who find a robust positive relationship between output and both public and private consumption.

Similarly, investment is strongly procyclical for the majority of countries in the sample, and almost all of these peak at a zero lag, which is identical to the finding of Rand and

[9] Both prices and inflation are strongly countercyclical in Malawi, Nigeria, Mexico, South Korea and Romania.

Tarp (2002). Two significant exceptions to this are Chile and Slovenia with very strongly countercyclical investment.

*(d) Public Sector Variables*

Fiscal policy can either dampen or exacerbate business cycle fluctuations depending on its timing. To have a stabilising effect on the economy, government expenditure should be countercyclical, whilst government revenues should be procyclical. Examining Tables 3.6(a), 3.6(b) and 3.6(c) reveals that there is no consistent relationship between output and government expenditures, or government revenues, for either the developed or developing countries. The US and the UK both exhibit strongly countercyclical government expenditures, whilst Japan has strongly procyclical government expenditures. However, upon reducing the time series for the developed countries to 1980:1 to 2005:1, government expenditures in the US and UK remain strongly countercyclical, whilst becoming acyclical in Japan. The situation is worse for the developing countries, where it is even more critical for business cycle fluctuations to be smoothed, with evidence of strongly countercyclical expenditure in just three of the developing countries, whilst there is evidence of strongly procyclical expenditures in seven countries.

Furthermore, just six of the developing countries exhibit procyclical government revenues, whilst eleven of the developing countries have strongly countercyclical government revenues. Thus, the governments in these countries need to address their revenue sources to ensure these do not reinforce fluctuations in the business cycle. Agénor *et al.* (2000) similarly find countercyclical government revenues and suggest this is likely to result from the negative effects of increases in tax revenues; however, this is based on a sample of just four developing countries.

To measure the net effect of government expenditure and revenue on the domestic business cycle, the fiscal impulse is used. The fiscal impulse, as defined by Agénor *et al.* (2000), is the ratio of government expenditures to government revenue, and to be a stabilising influence on the business cycle it should be countercyclical. Eleven of the developing countries have significantly countercyclical fiscal impulses. However, five countries have significantly procyclical fiscal impulses, of which three are Eastern European countries.

*(e) Money, Credit and Interest Rates*

Monetary policy is an important tool in macroeconomic stabilisation. However, the question of whether changes in money actually cause output fluctuations remains a pertinent one, both for developed and developing countries.[10] It is, thus, important to examine the relationship between the business cycle and monetary variables.

The first relationship is that between the business cycle and broad money.[11] Examination of Tables 3.6(a), (b) and (c) reveals that, on average, broad money is either weakly procyclical or acyclical. However, money is countercyclical in a number of developing countries; Hungary, Nigeria, Tunisia, Peru and Trinidad and Tobago. From the correlations between the business cycle and leads and lags of broad money, it is possible to both assess whether money leads or lags the cycle. Additionally, if money leads the cycle, it is important to assess the speed at which changes in money are transmitted to economic activity. Firstly, for the developed countries, money leads the cycle in both the US and Japan and innovations in money are transmitted fairly quickly; within one quarter for Japan and within three quarters for the US. However, broad money appears to lag the business cycle in the UK, thus suggesting that money is influenced by output, rather than influencing it. Secondly, excluding the countries for which money is countercyclical, this relationship is examined for the developing countries. This analysis reveals that money leads the cycle for eleven, is synchronous for four and lags the cycle for seven developing countries. For all of the countries in which money leads the cycle, monetary innovations are transmitted within three quarters.

To further examine whether *money causes output*, Granger causality tests of the cyclical components of broad money and output were performed. The results provide evidence that *money causes output* in a number of countries, including the US, Japan, Brazil, Chile, Côte D'Ivoire, Lithuania, South Africa and South Korea. Conversely, there was also evidence that *output causes money* in several countries; Hungary, Malawi, Turkey and Trinidad and Tobago. In all other countries there was no clear pattern of causality. However the results were often sensitive to the choice of lags; the results for four and eight lags are available in Appendix B. The Granger causality tests and the examination of whether money leads or lags the business cycle, provide some evidence to suggest that money does influence output in developing countries. Monetary shocks are, therefore, important sources of business cycle fluctuations.

Following Agénor *et al*. (2000), the broad money velocity indicator is used to examine the velocity of money. The contemporaneous correlations are strongly countercyclical for all

[10] For example, see Sims (1972, 1980), Christiano and Ljungqvist (1988), Hafer and Kutan (2001) and Rusek (2001)

[11] The results of correlations between output and the other monetary aggregates (reserve money, narrow money (M1) and quasi money) follow a very similar pattern to those for broad money; consequently this analysis follows Agénor *et al.* (2000) and concentrates solely on broad money.

countries, with the exception of the UK and Mexico. This exactly corresponds to the findings of Agénor *et al*. (2000).

Another monetary variable which has been found by Agénor *et al*. (2000) and Rand and Tarp (2002) to have an important influence on the business cycle in some developing countries is real domestic private sector credit. Since equity markets are weakly capitalised in developing countries, relative to the industrialised countries, domestic private sector credit is thought to fulfil an important role in determining investment and hence economic activity in these countries. From Tables 3.6(a), (b) and (c) it is apparent that there is no clear pattern of cyclicality between output and real domestic private sector credit amongst the developing countries. However, it is procyclical for eighteen of the thirty-two countries. In the developed countries, where private sector credit should play a less important role, it is strongly procyclical. To examine whether credit influences output or vice versa, it is necessary to examine whether credit leads or lags the business cycle. For the majority of countries credit lags the business cycle, thus suggesting that it is fluctuations in output that influence credit. There are just three countries in which credit is both procyclical and leads the cycle: Japan, Peru and Nigeria. Granger causality test reveal a similar picture, with either no clear pattern of causation or with output causing credit; the only two countries for which there is significant evidence that credit causes output are Chile and Japan.

Finally, when considering the impact of monetary policy on the business cycle, it is also necessary to examine the relationship between output and interest rates. This relationship was not considered in either Agénor *et al*. (2000) or Rand and Tarp (2002). However, Neumeyer and Perri (2005) find real interest rates to be mildly procyclical in developed countries and countercyclical in developing countries. This is based on results for Argentina, Brazil, Korea, Mexico, and the Philippines. Similarly, Uribe and Yue (2005) find real interest rates to be countercyclical in five developing economies:[12] Argentina, Brazil, Ecuador, Mexico and Peru.

Tables 3.6(a), (b) and (c) report the correlations between output and both the real money market rate and the real lending rate. Both real interest rate variables are procyclical in the developed countries, and strongly so in the US and Japan. However, the results for the developing countries are much more varied. On average real interest rates are weakly procyclical in Africa, North Africa, Asia and Eastern Europe and countercyclical in Latin America. This countercyclicality of interest rates may be explained by the use of interest

[12] Uribe and Yue (2005) find real interest rates to be acyclical in the Philippines and South Africa, the only other developing countries in their sample.

rates to target inflation during the 1980s and early 1990s, when most of the Latin American countries experienced a combination of extremely high inflation rates and slow economic growth. Thus, the distinct countercyclical relationship that Neumeyer and Perri (2005) and Uribe and Yue (2005) document is not characteristic of most developing country business cycles. This finding is particularly significant as there have been several recent papers that incorporate this feature into theoretical models of emerging market business cycles, including Neumeyer and Perri (2005), Uribe and Yue (2005), Aguiar and Gopinath (2006) and Arellano (2008).

Examining whether the real interest rates lead or lag the cycle, it is evident that these lag the cycle by around three quarters in the developed countries, whilst they tend to lead the cycle in the North African and Eastern European countries. There is no clear pattern amongst the other regions. To further consider whether interest rates cause the business cycle, Granger causality tests were used. These revealed that real interest rates cause output in one third of the developing countries,[13] whilst being caused by output in just four developing countries; for all the other countries, including the developed countries, there was no evidence of unidirectional causation. Thus, interest rates do appear to be an important source of business cycle movements in developing countries.

*(f) Trade and Exchange Rates*

The final correlation analysis concerns the relationship between the business cycle and trade related variables, including the trade balance, the terms of trade and exchange rates. Following Agénor *et al*. (2000), the trade balance is constructed as the ratio of exports to imports at current prices.

Firstly, imports and exports are strongly procyclical in the developed countries, and are correspondingly procyclical in the majority of the developing countries. The only significant exceptions to this are Chile and India which have weakly and strongly countercyclical imports respectively. However, the results for the trade balance are not as consistent; for the developed countries and sixteen of the developing countries the trade balance is countercyclical, whilst for seven countries it is procyclical, and strongly so in Chile, Nigeria and Tunisia. The procyclicality of the trade balance can be explained by the strong positive relationship between the business cycle and exports and the acyclicality of imports, which in combination will result in a positive trade balance during expansions and a negative trade balance during recessions. This is the opposite of the developed country

[13] Brazil, Chile, South Korea, Malaysia, Mexico, Nigeria, Peru, Senegal, Slovenia, South Africa and Turkey.

case, where expansionary business cycle phases result in increased demand for imports and thus a negative trade balance. The close relationship between exports and the business cycle in these countries may extend from the implementation of export-led or outward-looking development strategies.

The terms of trade provide an interesting distinction between the developed and the developing countries. Terms of trade are countercyclical for the developed countries. However, just three of the developing countries are similarly countercyclical (Brazil, Morocco and Hong Kong); for the majority the terms of trade are strongly procyclical. This is similar to the findings of both Agénor *et al*. (2000) and Rand and Tarp (2002), although for somewhat smaller samples. Agénor *et al*. (2000) suggest that, under the assumption that the developing economies are too small to affect world prices, the procyclical relationship may reflect demand shifts that yield simultaneous increases in world prices and demand for the country's exports. As such, both the economy's terms of trade and output would increase.

The weak relationship between the exchange rate and the rest of the economy is well documented in the literature, and is known as the *exchange rate disconnect puzzle* following Obstfeld and Rogoff (2000). Thus, it is unlikely that there will be a clear pattern of correlations between output and exchange rates for the sample of developing countries. However, for completeness this relationship is considered.

For the developed countries, both the nominal and real effective exchange rates are countercyclical, although as expected there is no clear configuration between the developing countries. The only distinct pattern that emerges is that for most countries both nominal and real exchange rates exhibit the same cyclicality relationship. A similar pattern is observed by Agénor *et al*. (2000).

### *3.5.4. Cross-Correlation of Output between Countries*

The final intention of this chapter is to examine the degree of business cycle synchronisation by measuring pair-wise correlations, both between developing countries and between developing and developed countries. There is known to be a close relationship between industrialised country business cycles; for example, Backus, Kehoe and Kydland (1995) find strong positive correlations between US output and nine other industrialised country business cycles.[14] However, the degree of synchronisation for developing country cycles is rather more varied. Kose *et al.* (2003) find that a "world factor" explains much of the variation in industrialised country business cycles, whilst developing country business cycle fluctuations tend to be country specific, particularly in Asia and Africa, and consequently they display little comovement with the rest of the world.

There is reason to believe that the business cycles of developing countries will be correlated with the business cycles of their major trading partners and investors. As discussed in Aruoba (2001), a procyclical and leading relationship is expected between the lender country's business cycle and the receiving country's cycle. However, the results show no clear relationship between the business cycles of Turkey and its lender countries. A similarly procyclical and leading relationship is to be expected between a developing country's cycle and the countries that are the key recipients of its exports. If the purchasing country goes into a recession, their import demand will decrease and hence the developing country's exports will decline stimulating the onset of a recession. However, Caldéron *et al.* (2007) find that whilst trade intensity is an important factor in increasing business cycle synchronisation amongst the industrialised countries, this is of significantly less importance in the synchronisation between developed and developing country cycles and between developing country cycles.

Table 3.7 details the cross-country correlations, and as expected there is very strong synchronisation of the US, UK and Japanese business cycles, whilst the degree of synchronisation for the developing countries is rather more varied.

Examining the correlation between the developed and developing country pairs, there is evidence of strong synchronisation for a large proportion of the developing countries, particularly within the Latin American and Asian regions. In most cases where there is a significant correlation, the developed country is one of the key purchasers of the developing country's exports; for example, throughout the sample period the US was the main procurer of Colombia's exports.

[14] The industrialised countries include Australia, Austria, Canada, France, Germany, Italy, Japan, Switzerland and the UK.

**Table 3.7**

## Cross-Correlations of Real Output between Countries

| | US | UK | JP | AG | BB | BR | CB | CL | MX | PE | TT | UG | BG | HK | IN | KO | MY | PK | PH | TK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| US | . | 0.65* | 0.62* | 0.55* | 0.30* | 0.18 | 0.32* | 0.43* | 0.23* | 0.05 | 0.04 | 0.34* | -0.08 | 0.37* | 0.21 | 0.28* | 0.45* | 0.09 | -0.03 | 0.20 |
| UK | | . | 0.46* | 0.36* | 0.17 | 0.35* | 0.16 | 0.18 | -0.07 | 0.01 | -0.07 | -0.01 | -0.16 | 0.24* | 0.27* | 0.38* | 0.40* | 0.01 | 0.06 | -0.06 |
| JP | | | . | 0.50* | 0.40* | 0.45* | 0.09 | 0.25* | 0.27* | -0.13 | 0.00 | 0.17 | -0.22* | 0.16 | 0.28* | 0.34* | 0.48* | 0.10 | 0.40* | 0.27* |
| AG | | | | . | 0.34* | 0.10 | 0.15 | 0.47* | 0.51* | 0.09 | -0.02 | 0.58* | -0.05 | -0.01 | 0.17 | -0.11 | 0.32* | 0.02 | -0.21 | 0.63* |
| BB | | | | | . | 0.08 | 0.07 | 0.03 | 0.06 | -0.11 | 0.19 | 0.16 | -0.20 | -0.10 | 0.37* | 0.08 | 0.18 | -0.10 | -0.10 | 0.15 |
| BR | | | | | | . | 0.12 | -0.15 | 0.05 | 0.62* | -0.02 | 0.03 | 0.20 | 0.45* | 0.10 | 0.22* | 0.39* | -0.09 | 0.32* | -0.01 |
| CB | | | | | | | . | 0.46* | 0.09 | 0.42* | 0.36* | 0.44* | 0.29* | 0.31* | 0.05 | -0.07 | 0.20 | 0.24* | 0.17 | 0.26* |
| CL | | | | | | | | . | 0.08 | 0.15 | 0.19 | 0.52* | -0.15 | 0.42* | -0.12 | 0.03 | 0.20 | 0.07 | 0.17 | 0.20 |
| MX | | | | | | | | | . | 0.02 | 0.01 | 0.37* | -0.10 | -0.21 | -0.15 | -0.21 | 0.04 | 0.13 | -0.16 | 0.19 |
| PE | | | | | | | | | | . | 0.44* | 0.46* | 0.32* | 0.25* | 0.17 | 0.16 | 0.02 | 0.08 | 0.14 | 0.19 |
| TT | | | | | | | | | | | . | 0.32* | 0.05 | 0.14 | 0.00 | 0.04 | -0.05 | 0.19 | -0.06 | 0.10 |
| UG | | | | | | | | | | | | . | 0.18 | 0.38* | 0.22* | 0.02 | 0.00 | 0.07 | -0.09 | 0.24* |
| BG | | | | | | | | | | | | | . | 0.28* | 0.08 | 0.02 | 0.07 | 0.23* | 0.23* | 0.08 |
| HK | | | | | | | | | | | | | | . | 0.16 | 0.50* | 0.34* | -0.12 | 0.32* | -0.07 |
| IN | | | | | | | | | | | | | | | . | 0.32* | 0.26* | -0.20 | 0.24* | 0.13 |
| KO | | | | | | | | | | | | | | | | . | 0.36* | -0.13 | 0.49* | -0.12 |
| MY | | | | | | | | | | | | | | | | | . | -0.03 | 0.43* | 0.02 |
| PK | | | | | | | | | | | | | | | | | | . | -0.06 | 0.27* |
| PH | | | | | | | | | | | | | | | | | | | . | 0.02 |
| TK | | | | | | | | | | | | | | | | | | | | . |
| IV | | | | | | | | | | | | | | | | | | | | |
| MI | | | | | | | | | | | | | | | | | | | | |
| NG | | | | | | | | | | | | | | | | | | | | |
| SG | | | | | | | | | | | | | | | | | | | | |
| SA | | | | | | | | | | | | | | | | | | | | |
| IS | | | | | | | | | | | | | | | | | | | | |
| JO | | | | | | | | | | | | | | | | | | | | |
| MC | | | | | | | | | | | | | | | | | | | | |
| HN | | | | | | | | | | | | | | | | | | | | |
| LT | | | | | | | | | | | | | | | | | | | | |
| MK | | | | | | | | | | | | | | | | | | | | |
| RM | | | | | | | | | | | | | | | | | | | | |
| SX | | | | | | | | | | | | | | | | | | | | |
| SJ | | | | | | | | | | | | | | | | | | | | |

| | IV | MI | NG | SG | SA | IS | JO | MC | HN | LT | MK | RM | SX | SJ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| US | 0.09 | 0.05 | 0.17 | -0.15 | 0.04 | 0.16 | 0.20 | 0.07 | 0.46* | 0.06 | 0.23* | 0.12 | -0.29* | -0.01 |
| UK | 0.10 | 0.01 | 0.16 | -0.25* | -0.04 | 0.21 | 0.07 | 0.20 | 0.61* | -0.12 | -0.07 | 0.42* | 0.02 | 0.29* |
| JP | -0.07 | 0.21 | 0.30* | -0.17 | 0.23 | 0.06 | 0.06 | 0.21 | 0.21 | -0.25* | 0.01 | 0.37* | 0.16 | 0.26* |
| AG | -0.10 | 0.41* | 0.02 | -0.22* | -0.34* | 0.24* | -0.34* | 0.11 | 0.21 | 0.08 | 0.23* | -0.26* | -0.12 | -0.09 |
| BB | 0.14 | 0.09 | 0.19 | 0.02 | 0.05 | -0.07 | 0.12 | 0.14 | 0.26* | 0.01 | 0.01 | 0.23* | 0.03 | 0.22 |
| BR | 0.03 | 0.10 | 0.00 | -0.20 | 0.42* | 0.35* | 0.21 | 0.03 | 0.30* | -0.18 | -0.14 | 0.42* | 0.09 | 0.41* |
| CB | 0.25* | -0.01 | 0.03 | 0.16 | 0.19 | 0.11 | 0.31 | -0.06 | 0.07 | 0.32* | -0.16 | 0.11 | 0.45* | 0.17 |
| CL | 0.10 | 0.05 | 0.31* | -0.12 | 0.01 | -0.15 | 0.20 | -0.12 | -0.06 | 0.07 | 0.05 | 0.01 | 0.21 | 0.07 |
| MX | 0.06 | 0.11 | 0.32* | -0.05 | 0.20 | -0.03 | 0.01 | 0.02 | -0.12 | 0.02 | 0.36* | -0.28* | -0.48* | -0.01 |
| PE | 0.59* | -0.31* | 0.03 | 0.05 | 0.13 | 0.25* | 0.26* | -0.22* | 0.15 | -0.23* | -0.29* | 0.12 | 0.27* | 0.44* |
| TT | 0.23* | -0.15 | -0.06 | 0.21 | -0.09 | 0.11 | 0.10 | 0.01 | -0.13 | 0.02 | -0.10 | -0.09 | 0.26* | 0.29* |
| UG | 0.40* | -0.11 | 0.17 | 0.06 | 0.21 | 0.13 | 0.20 | -0.01 | 0.09 | 0.06 | 0.26* | 0.03 | 0.07 | 0.24* |
| BG | -0.04 | -0.16 | -0.36* | 0.07 | 0.24* | 0.13 | 0.21 | -0.07 | 0.12 | 0.20 | -0.20 | 0.07 | 0.17 | 0.27* |
| HK | 0.04 | -0.12 | -0.10 | -0.20 | 0.35* | 0.40* | 0.16 | -0.01 | 0.32* | 0.04 | -0.21 | 0.21 | 0.21 | 0.39* |
| IN | 0.12 | -0.01 | 0.02 | 0.06 | 0.08 | 0.30* | 0.13 | 0.11 | 0.47* | -0.22 | -0.13 | 0.41* | 0.25* | 0.31* |
| KO | 0.03 | -0.01 | -0.11 | -0.19 | -0.04 | 0.23* | 0.12 | 0.06 | 0.34* | -0.35* | -0.06 | 0.29* | -0.04 | 0.24* |
| MY | -0.10 | 0.03 | 0.05 | -0.36* | 0.49* | -0.05 | 0.02 | 0.12 | 0.42* | -0.30* | -0.02 | 0.44* | 0.21 | 0.27* |
| PK | 0.01 | 0.07 | 0.03 | 0.15 | 0.05 | -0.03 | 0.10 | -0.12 | -0.13 | 0.11 | 0.09 | -0.13 | 0.02 | 0.00 |
| PH | -0.14 | 0.00 | -0.03 | -0.15 | 0.43* | 0.12 | 0.07 | -0.04 | 0.03 | -0.24* | -0.23* | 0.48* | 0.18 | 0.17 |
| TK | 0.14 | 0.25* | 0.17 | 0.08 | -0.09 | 0.23* | 0.08 | -0.12 | -0.08 | 0.25* | 0.11 | -0.07 | 0.03 | -0.19 |
| IV | . | -0.20 | 0.16 | 0.07 | -0.07 | -0.01 | 0.10 | -0.01 | 0.11 | 0.10 | -0.13 | 0.02 | -0.18 | -0.01 |
| MI | | . | -0.05 | 0.03 | -0.04 | -0.03 | -0.07 | 0.25* | -0.20 | -0.22* | -0.10 | -0.03 | 0.34* | 0.20 |
| NG | | | . | -0.01 | 0.10 | -0.02 | -0.20 | 0.12 | 0.06 | -0.09 | 0.19 | 0.11 | 0.22* | 0.15 |
| SG | | | | . | -0.33* | -0.15 | 0.12 | 0.05 | -0.18 | 0.05 | -0.08 | -0.21 | 0.09 | -0.13 |
| SA | | | | | . | -0.15 | -0.07 | -0.06 | 0.35* | -0.21 | -0.34* | 0.63* | 0.46* | 0.31* |
| IS | | | | | | . | 0.13 | -0.10 | 0.11 | -0.07 | 0.13 | -0.09 | 0.11 | 0.34* |
| JO | | | | | | | . | -0.09 | -0.03 | 0.24* | -0.29* | 0.02 | 0.10 | 0.32* |
| MC | | | | | | | | . | -0.11 | -0.22* | -0.08 | 0.07 | -0.02 | 0.31* |
| HN | | | | | | | | | . | 0.03 | -0.07 | 0.53* | 0.07 | 0.26* |
| LT | | | | | | | | | | . | 0.04 | -0.47* | -0.03 | -0.20 |
| MK | | | | | | | | | | | . | -0.28* | -0.16 | -0.29* |
| RM | | | | | | | | | | | | . | 0.47* | 0.24* |
| SX | | | | | | | | | | | | | . | 0.46* |
| SJ | | | | | | | | | | | | | | . |

Note that numbers marked in bold indicate weak contemporaneous correlation and numbers marked in bold with a * indicate strong contemporaneous correlation

Examining the degree of synchronisation between developing country cycles reveals no clear picture. The results for Africa seem to concur with the findings of Kose *et al.* (2003), namely that fluctuations are country specific. However, the Asian countries appear to exhibit strong regional synchronisation, particularly when considering only the East Asian countries; the correlations for this sub-sample of countries are presented in Table 3.8. There are also a number of strong correlations between the Latin American countries, and particularly between the members of the Latin American Free Trade Association.[15]

**Table 3.8 Cross-Correlations of Real Output between East Asian Countries**

| | JP | HK | IN | KO | MY | PH |
|---|---|---|---|---|---|---|
| JP | . | 0.16 | 0.28* | 0.34* | 0.48* | 0.40* |
| HK | | . | 0.16 | 0.50* | 0.34* | 0.32* |
| IND | | | . | 0.32* | 0.26* | 0.24* |
| KO | | | | . | 0.36* | 0.49* |
| MY | | | | | . | 0.43* |
| PH | | | | | | . |

Finally, the patterns of business cycle synchronisation observed in this analysis are compared to those found using the concordance statistic in Chapter 2. This reveals that whilst no country pair with a significant concordance statistic is found to have an insignificant correlation in this analysis, a large number of the strong procyclical correlations observed in Table 3.7 are not similarly significant in the concordance analysis. In particular, referring to the East Asian countries in Table 3.8, the only significant concordance statistics are between India and South Korea and between Malaysia and the Philippines. Thus, this suggests that the concordance statistic is a much more robust measure of business cycle synchronisation and furthermore, that observed patterns of business cycle synchronisation clearly depend on the choice of business cycle definition.

## 3.6. CONCLUSION AND SUMMARY OF STYLISED FACTS

Identifying the characteristics and statistical properties (or stylised facts) of business cycles is essential as these often form the basis for the construction and validation of theoretical business cycle models. Furthermore, understanding the cyclical patterns in economic activity, and their causes, is important to the decisions of both policymakers and market participants. However, whilst there have been a number of research papers examining these stylised facts in the context of developing countries (e.g. Agénor *et al.*, 2000; Rand

[15] The seven members are Argentina, Brazil, Chile, Mexico, Paraguay, Peru and Uruguay.

and Tarp, 2002; Neumeyer and Perri, 2005; Aguar and Gopinath, 2007), these have been based on very small samples and the results have consequently been subjective and dependent on the countries chosen for inclusion in the study.

Motivated by the importance of the stylised facts and the lack of consistency amongst previous researchers, this chapter has made a significant contribution to the literature by both generalising the developing country stylised facts for a much larger sample of thirty-two countries, and constructing a more comprehensive set of stylised facts. The stylised facts emerging from this study are summarised below.

Firstly, output is on average twice as volatile in developing than developed countries. This contradicts the finding of Rand and Tarp (2002) who state that output is no more than 20% more volatile in developing countries.

Secondly, with the exception of the Latin American countries, the volatility of prices and wages are similar to those of the developed countries. There is no clear pattern of either pro- or countercyclicality of either prices or inflation amongst the developing countries. There is, however, a tendency for those developing countries with countercyclical CPI to also exhibit countercyclical inflation and vice versa. This is a significant difference from the pattern of procyclical inflation and countercyclical prices observed in the industrialised countries. Real wages, however, are procyclical for both developing and developed countries.

Thirdly, consumption and investment are significantly more volatile than in developed countries. Consumption is on average 30% more volatile than output, whilst investment is between two and four times more volatile than output. Both investment and consumption are procyclical, as observed in developed countries. The findings for consumption and investment are consistent with the previous literature.

Fourthly, government revenue and expenditure are significantly more volatile than in developed countries, and they are, on average, four times more volatile than output. There is less consistency in the correlation analysis; however the fiscal impulse is significantly countercyclical for the majority of the developing country correlations, which implies that fiscal policy is having a stabilising effect on business cycle fluctuations.

Fifthly, real interest rates are, on average, less volatile than in the developed countries; this is the opposite of the finding of Neumeyer and Perri (2005). On average real interest rates are weakly procyclical in Africa, North Africa, Asia and Eastern Europe and countercyclical in Latin America. Thus, the distinct countercyclical relationship that

Neumeyer and Perri (2005) and Uribe and Yue (2005) document is not characteristic of most developing country business cycles. This finding is particularly significant as there have been several recent papers that incorporate this feature into theoretical models of emerging market business cycles, including Neumeyer and Perri (2005), Uribe and Yue (2005), Aguiar and Gopinath (2006) and Arellano (2008).

Sixthly, broad money is, on average, procyclical in developed countries and either weakly procyclical or acyclical in developing countries. There is evidence that money leads the business cycle in a number of developing countries, suggesting that money does influence output in developing countries, and thus that monetary shocks are important sources of business cycle fluctuations. The broad money velocity indicator is strongly countercyclical in all the developing countries, except Mexico, exactly corresponding to the findings of Agénor *et al*. (2000).

Seventhly, real private sector domestic credit is procyclical in most developing countries, as by Agénor *et al*. (2000) and Rand and Tarp (2002). However, it tends to lag rather than lead the business cycle, thus suggesting that it is fluctuations in output that influence credit rather than credit influencing the business cycle.

Eighthly, output fluctuations in developing countries are positively correlated with economic activity in the main industrialised countries, as proxied by world output and world real interest rate. Findings for both of world output and world real interest rate are consistent with Agénor *et al.* (2000). Furthermore, examining the correlation between the developed and developing country pairs, there is evidence of strong synchronisation for a large proportion of the developing countries, particularly within the Latin American and Asian regions.

Ninthly, imports and exports are strongly procyclical in the developed countries and are correspondingly procyclical in the developing countries. However, there is no consistent relationship with the trade balance. The terms of trade provide an interesting distinction between the developed and the developing countries, being countercyclical for the developed countries and strongly procyclical for the majority of developing countries. This is similar to the findings of both Agénor *et al*. (2000) and Rand and Tarp (2002), although for somewhat smaller samples.

Tenthly, nominal and real effective exchange rates are countercyclical in developed countries. However, there is no clear configuration between the developing countries. The only distinct pattern that emerges is that for most countries both nominal and real exchange rates exhibit the same cyclicality relationship. A similar pattern is observed by Agénor *et* *al*. (2000). However, fluctuations in real exchange rates are persistent and volatile, which is consistent with the findings for the developed countries.

Finally, a central characteristic of developed country business cycles that has concerned macroeconomists in recent years is the persistence of output fluctuations. This analysis has found that the developing country business cycles are also characterised by significantly persistent output fluctuations. The magnitude of this persistence is, however, somewhat lower than for the developed countries. Furthermore, prices and nominal wages are significantly persistent in developing countries. This finding is important, because it justifies the use of theoretical models with staggered prices and wages for the modelling of developing country business cycles.

Together with the business cycle characteristics identified in Chapter 2, these act to extend the existing knowledge of developing country business cycles and provide a significant generalisation of the stylised facts. This is important both for use in subsequent theoretical modelling and to inform the decisions of policymakers and market participants alike.

# CHAPTER 4

## *"The Output Persistence Problem: A Critical Review of the New Keynesian Literature"*

### 4.1. INTRODUCTION

Business cycles of both developed and developing countries are characterised by persistent output fluctuations. [1] Consequently, this has received much interest amongst macroeconomists. In particular, New Keynesian economists have stressed the importance of imperfect competition and nominal rigidities in generating persistent output fluctuations in response to monetary policy shocks. However, the *output persistence problem* can be defined as the inability of such theoretical business cycle models to match the observed magnitude of output persistence without staggered prices, or wages, that are set for exogenously long periods of time.

Intuitively, the introduction of nominal rigidities provides a promising avenue to explain the non-neutrality of money (Ball and Romer, 1990). Under fully flexible prices, any increase in nominal money supply will be reflected in a proportionate increase in the price level. Thus, the expansionary policy will have no effect on output; money is neutral. However, in the presence of nominal rigidities, money can have real effects on output. The duration of this effect, however, is dependent on the extent of the nominal rigidity; if prices are not permanently fixed, then over time prices will adjust and the effects of the monetary policy on output and interest rates will disappear. Given this, it would be possible to match the observed output persistence by exogenously imposing a corresponding period of rigidity. However, this is not an empirically pleasing idea. Thus, the problem in the literature is to establish a mechanism to endogenise the nominal rigidity.

The initial progress comes from the work of Taylor (1980) and Blanchard (1983, 1986) who explore the issue of output persistence in the context of either staggered price or wage contracts. Taylor (1980), for example, argues that:

> "*Because of the staggering, some firms will have established their wage rates prior to the current negotiations, but others will establish their wage rates in*

[1] As revealed in Chapter 3.

> *future periods. Hence, when considering relative wages, firms and unions must look both forward and backward in time to see what other workers will be paid during their own contract period. In effect, each contract is written relative to other contracts, and this causes shocks to be passed on from one contract to another . . . contract formation in this model generates an inertia of wages*" (p.2)

This appears to provide a promising mechanism to generate long periods of endogenous stickiness from short periods of exogenous stickiness, which should in turn generate much more persistent movements in output than in a similar model with synchronised price-setting.

Chari, Kehoe and McGrattan (2000), carry this intuition to a general equilibrium environment to examine whether a model where imperfectly competitive firms set prices in a staggered fashion can generate persistent movements in output in response to a monetary policy shock. Rather surprisingly, their main finding is that a staggered price mechanism is, by itself, incapable of generating persistent output fluctuations beyond the exogenously imposed contract rigidity; aggregate output returns to its steady-state level as soon as the contract has been renewed.

In light of this finding, many authors proposed alternative specifications for the sticky price model, such as the application of translog, rather than constant elasticity of substitution (CES), preferences; and the inclusion of an input-output structure, in order that the price-setting rule be a function of competitors prices rather than a simple mark-up over marginal costs as in Chari *et al*. (2000) (see Bergin and Feenstra (1998) for example). These adaptations do act to improve the sticky price model, though the level of output persistence generated remained significantly below that observed in the data.

Since conventional wisdom, following Taylor (1980), implied the equivalence of staggered price and wage setting, little work was carried out with the alternative sticky wage mechanism. However, important work by Huang and Liu (2002) scrutinized this presumed equivalence finding staggered price and wage setting to have quite different implications for persistence. Staggered wage setting is perfectly able to generate significant output persistence in response to monetary shocks, whilst staggered price setting is incapable of doing so.

Nevertheless, a model with just staggered wage setting, although able to generate the desired output persistence, produces real wages which are weakly countercyclical. This is inconsistent with the increasingly procyclicality of real wages in recent years, in both developed and developing countries. The sticky price model, on the other hand, generates procyclical wages but no output persistence. Thus, perhaps a combined model with sticky prices, sticky wages and an input-output structure, such as that proposed by Huang *et al.* (2004) is required.

This chapter investigates the output persistence problem and examines the suggestions in the New Keynesian literature to overcome this phenomenon, including the incorporation of an input-output structure and the use of firm specific capital. The following section details the Chari *et al*. (2000) dynamic general equilibrium model with sticky prices and examines the inability of the staggered price mechanism, by itself, to generate persistent output fluctuations beyond the exogenously imposed contract rigidity. In light of this, section three examines some of the alternative specifications for the sticky price model to see if they are any more successful. Section four, then examines the equivalence of staggered price and wage setting, drawing on the influential work of Huang and Liu (2002), and formally explores the implications of the two staggering mechanisms for the persistence problem. The penultimate section examines the responses of the various model specifications to an expansionary monetary policy shock, examining the degree of output persistence generated, as well as the models' ability to emulate other key business cycle characteristics. The final section concludes with a summary of the key insights and failures of the models considered and a brief discussion of areas for future research and the applicableness of such models to developing country business cycles.

## 4.2. THE STICKY PRICE MODEL

The initial model examined is the seminal sticky price model of Chari *et al*. (2000). However, as the analysis will demonstrate, the model is incapable of reproducing the desired output persistence.

### *4.2.1. The Basic Sticky Price Model – Chari, Kehoe and McGrattan (2000)*

This details the benchmark monetary economy of Chari *et al*. (2000), which consists of a large number of infinitely lived consumers, a large number of perfectly competitive final goods firms and a continuum of intermediate goods firms indexed by $i \in [0,1]$. The intermediate goods producers are monopolistically competitive and set prices in a staggered fashion.

In each period t, the economy experiences one of many events (monetary shocks) $s_t$. The history of events up to and including period t is given by $s^t = (s_0,\ldots,s_t)$ and the probability of any particular history $s^t$ is $\pi(s^t)$.

Final Good Producers

Final goods $y(s^t)$ are produced from intermediate goods with $y(i,s^t)$ according to the production function:

$$y\left(s^t\right)=\left[\int y\left(i,s^t\right)^{\theta_x} di\right]^{\frac{1}{\theta_x}} \tag{4.1}$$

where, $1/(1-\theta_x)$ is the elasticity of substitution.

They are perfectly competitive, choosing inputs $y(i,s^t)$ for all $i \in [0,1]$ and output $y(s^t)$ to maximise profits (4.2), subject to (4.1).

$$\max\ \bar{P}\left(s^t\right)y\left(s^t\right)-\int P\left(i,s^{t-1}\right)y\left(s^t\right)di \tag{4.2}$$

where, $\bar{P}\left(s^t\right)$ is the price of the final good in period t and $P\left(i,s^{t-1}\right)$ is the price of the intermediate good i in period t.

Solving the profit maximisation problem for the final good producers yields the input-demand function:

$$y^d\left(i,s^t\right)=\left[\frac{\bar{P}\left(s^t\right)}{P\left(i,s^{t-1}\right)}\right]^{\frac{1}{1-\theta_x}} y\left(s^t\right) \tag{4.3}$$

Furthermore, since the final good producers are perfectly competitive this implies that in equilibrium the output price in period t $\bar{P}\left(s^t\right)$ depends only on the history of events up to and including t-1, but not period t.

$$\bar{P}\left(s^t\right)=\left[\int P\left(i,s^{t-1}\right)^{\frac{\theta_x}{\theta_x-1}} di\right]^{\frac{\theta_x-1}{\theta_x}} \tag{4.4}$$

Intermediate Good Producers

At time t, intermediate good i is produced by a monopolist according to a Cobb-Douglas production function:

$$y\left(i,s^t\right)=F\left[k\left(i,s^t\right),l\left(i,s^t\right)\right]=k\left(i,s^t\right)^{\alpha} l\left(i,s^t\right)^{1-\alpha} \tag{4.5}$$

where, $k\left(i,s^t\right)$ and $l\left(i,s^t\right)$ are capital and labour inputs respectively; and $\alpha \in (0,1)$ is the capital share.

Intermediate good producers are price takers in the factor markets and imperfect competitors in the intermediate good market, setting prices in a staggered fashion. In each period t, 1/N of these producers choose new prices $P\left(i,s^{t-1}\right)$ before the realisation of event $s_t$. These prices remain fixed for N periods, such that $P\left(i,s^{t+\tau-1}\right)=P\left(i,s^{t-1}\right)$ for $\tau=0,\ldots,N$ and are chosen to maximise discounted profits from period t to t+N-1:

$$\max \sum_{\tau=t}^{t+N-1}\sum_{s^\tau} \mathrm{Q}\left(s^\tau \middle| s^{t-1}\right)\left[P\left(i,s^{t-1}\right)-\nu\left(s^\tau\right)\bar{P}\left(s^\tau\right)\right]y^d\left(i,s^\tau\right) \tag{4.6}$$

where, $\mathrm{Q}\left(s^\tau \middle| s^{t-1}\right)$ is the price of one dollar in $s^\tau$ in units of dollars at $s^{t-1}$ and $\nu\left(s^\tau\right)$ is the unit cost of production at $s^t$:

$$\nu\left(s^t\right)=\min_{\mathrm{k,l}}\ r\left(s^t\right)k+w\left(s^t\right)l \quad \text{subject to } \mathrm{F(k,l)}\geq 1 \tag{4.7}$$

where, $r\left(s^t\right)$ is the rental rate on capital and $w\left(s^t\right)$ is the real wage rate.

Given the production function (4.5), cost minimisation implies:

$$\left(\frac{1-\alpha}{\alpha}\right)\frac{k\left(i,s^t\right)}{l\left(i,s^t\right)}=\frac{w\left(s^t\right)}{r\left(s^t\right)} \tag{4.8}$$

The solution to the profit maximisation problem (4.6) yields the optimum pricing decision:

$$P\left(i,s^t\right)=\frac{\sum_{\tau=t}^{t+N-1}\sum_{s^\tau}\mathrm{Q}\left(s^\tau \middle| s^{t-1}\right)\bar{P}\left(s^\tau\right)^{\frac{2-\theta_x}{1-\theta_x}}\nu\left(s^\tau\right)y\left(s^\tau\right)}{\sum_{\tau=t}^{t+N-1}\sum_{s^\tau}\mathrm{Q}\left(s^\tau \middle| s^{t-1}\right)\bar{P}\left(s^\tau\right)^{\frac{1}{1-\theta_x}}y\left(s^\tau\right)} \tag{4.9}$$

This implies that in any period t, the factor demands $k\left(i,s^t\right)$ and $l\left(i,s^t\right)$ of producer i are made after the realisation of event $s_t$ and therefore depend on $s^t$.

<u>Households</u>

The consumer problem is to maximise their discounted utility function (4.10) after the realisation of event $s^t$

$$\sum_{t=0}^{\infty}\sum_{s^t}\beta^t\pi\left(s^t\right)U\left[c\left(s^t\right),l\left(s^t\right),M\left(s^t\right)/\bar{P}\left(s^t\right)\right] \tag{4.10}$$

subject to the following budget and borrowing constraints:

$$\bar{P}\left(s^t\right)\left[c\left(s^t\right)+k\left(s^t\right)\right]+M\left(s^t\right)+\sum_{s^{t+1}}Q\left(s^{t+1}\left|s^t\right.\right)B\left(s^{t+1}\right)$$
$$\leq\bar{P}\left(s^t\right)\left[w\left(s^t\right)l^d\left(s^t\right)+\left[r\left(s^t\right)+1-\delta\right]k\left(s^{t-1}\right)\right] \quad (4.11)$$
$$+M\left(s^{t-1}\right)+B\left(s^t\right)+\Pi\left(s^t\right)+T\left(s^t\right)$$

$$B\left(s^{t+1}\right)\geq\bar{B} \quad (4.12)$$

where, $\beta\in\left[0,1\right]$ is the discount factor, $\delta$ is the capital depreciation rate, $c\left(s^t\right),l\left(s^t\right),k\left(s^t\right),M\left(s^t\right)$ are consumption, labour, capital and nominal money balances respectively, $B\left(s^{t+1}\right),\Pi\left(s^t\right),T\left(s^t\right)$ are nominal one-period bonds, nominal profits distributed to the consumers from intermediate good producers and nominal transfers from the government respectively and $\bar{B}$ is some large negative number. Each of the nominal bonds costs $Q\left(s^\tau\left|s^{t-1}\right.\right)$ in state t and provides a claim to one dollar in state $s^{t+1}$.

The inclusion of real money balances $\left(M\left(s^t\right)/\bar{P}\left(s^t\right)\right)$ in the consumer's utility function is a commonplace in the literature, as it provides a relationship between aggregate spending and monetary policy and thus a transmission channel for the monetary shock (Ball and Romer, 1990).

<u>The Monetary Authority</u>

The nominal money supply process is given by:

$$M\left(s^t\right)=\mu\left(s^t\right)M\left(s^{t-1}\right) \quad (4.13)$$

where, $\mu\left(s^t\right)$ is a stochastic process.

The new money balances are distributed to the economy via lump-sum nominal transfers to the household:

$$T\left(s^t\right)=M\left(s^t\right)-M\left(s^{t-1}\right) \quad (4.14)$$

<u>Equilibrium</u>

The equilibrium for the Chari *et al.* (2000) benchmark economy is then a collection of allocations for consumers, intermediate good producers and final good producers, together with prices $w\left(s^t\right),r\left(s^t\right),Q\left(s^\tau\left|s^t\right.\right),\bar{P}\left(s^t\right),P\left(i,s^t\right),$ that satisfy the following conditions:

(i) taking prices as given, consumer allocations solve the consumer problem (4.10)

(ii) taking all prices, except their own, as given, each intermediate good producer's price solves (4.6)

(iii) taking prices as given, each final good producer's allocation solves (4.2)

(iv) factor markets and the bond market clear and the economy resource constraint holds. The resource constraint is given by:

$$c\left(s^t\right)+k\left(s^t\right)=y\left(s^t\right)+\left(1-\delta\right)k\left(s^{t-1}\right) \quad (4.15)$$

### *4.2.2. The Output Persistence Problem*

Following the exposition in Chari *et al.* (2000), this shall demonstrate why the benchmark sticky price model is unable to generate the desired persistent output fluctuations in response to monetary shocks.

To solve the model analytically, a simplified version of the model is considered, which abstracts from capital, considers just two cohorts of intermediate producers (N=2) and assumes a constant elasticity of substitution (CES) form for the utility function,[2] where the discount factor β is set equal to unity.

Following the analytics of Chari *et al.* (2000), yields a system of log-linearised equations with which to analyse the impact of monetary shocks on movements in prices, where $\hat{x}_{it}, \hat{x}_t, \hat{p}_t, \hat{w}_t, \hat{c}_t, \hat{y}_t$ and $\hat{m}_t$ represent logarithmic deviations from a steady-state for $P\left(i,s^{t-1}\right), P\left(s^{t-1}\right), \bar{P}\left(s^t\right), w\left(s^t\right), c\left(s^t\right), y\left(s^t\right)$ and $M\left(s^t\right)$ respectively:

1. A static money demand equation in which consumption equals real balances:

$$\hat{m}_t-\hat{p}_t=\hat{y}_t \quad (4.16)$$

2. The price level $\hat{p}_t$ is a weighted average of the individual prices

$$\hat{p}_t=\tfrac{1}{2}\hat{x}_t+\tfrac{1}{2}\hat{x}_{t-1} \quad (4.17)$$

[2] $U\left(c,l,\frac{M}{\bar{P}}\right)=\frac{1}{1-\sigma}\left[\left(\omega c^{\frac{\eta-1}{\eta}}+(1-\omega)\left(\frac{M}{\bar{P}}\right)^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}}\left(1-l\right)^{\psi}\right]^{1-\sigma}$

where, ω is the share parameter, η is interest elasticity, ψ is a weight on leisure and σ is risk aversion.

3. A price setting equation

$$\hat{x}_{it} = \tfrac{1}{2}\hat{x}_{t-1} + \tfrac{1}{2}\mathrm{E}_{t-1}\hat{x}_{t+1} + \gamma \mathrm{E}_{t-1}\left(\hat{y}_t + \hat{y}_{t+1}\right) \tag{4.18}$$

where, $\gamma = 1 + \dfrac{\theta_x \omega}{\psi}$ is the elasticity of the equilibrium real wage with respect to consumption.

The first equation in this system (4.16) implies that large movements in output in response to movements in money, requires small movements in the price level. However, the third equation (4.18) implies that large movements in output only have small effects on the price level if γ is small.

Thus, in order to demonstrate that the model is incapable of generating the desired output persistence in response to monetary shocks, it is necessary to examine the influence of γ. This is done, following Chari *et al.* (2000), by solving the system of log-linearised equations for $\hat{x}_t$, $\hat{p}_t$ and $\hat{y}_t$.

They obtain, by using (4.16) and (4.17) to substitute for $\hat{y}_t$ in (4.18) and rearranging for $\hat{x}_t$:

$$\hat{x}_t = a\hat{x}_{t-1} + \frac{2a\gamma}{1-\gamma}\mathrm{E}_{t\text{-}1}\sum_{i=0}^{\infty} a^i\left(\hat{m}_{t+i} + \hat{m}_{t+1+i}\right) \tag{4.19}$$

where, $a$ is the root with absolute value less than unity, which solves $a^2 - a\left(2\left(1+\gamma\right)/\left(1-\gamma\right)\right) + 1 = 0$

$$a = \frac{1-\sqrt{\gamma}}{1+\sqrt{\gamma}} \tag{4.20}$$

Simplifying and assuming $\hat{m}_t$ is a random walk gives $\hat{x}_t = a\hat{x}_{t-1} + (1-a)\hat{m}_{t-1}$, which can be re-written in terms of prices:

$$\hat{p}_t = a\hat{p}_{t-1} + \frac{1}{2}(1-a)\left(\hat{m}_{t-1} - \hat{m}_{t-2}\right) \tag{4.21}$$

Finally, Chari *et al.* (2000) use (4.16) to substitute for $\hat{p}_t$, yielding an equation to describe the persistence properties of output with respect to monetary policy shocks:

$$\hat{y}_t = a\hat{y}_{t-1} + \left(\hat{m}_t - \hat{m}_{t-1}\right) + \frac{1}{2}(1-a)\left(\hat{m}_{t-1} - \hat{m}_{t-2}\right) \tag{4.22}$$

Examination of equation (4.22) reveals that the persistence of output depends critically on the value of $a$ and hence γ. However, the specification for γ in (4.18) necessitates that γ is greater than one, implying that $a$ is negative. Consequently, the benchmark sticky price model is incapable of generating persistent output fluctuations in response to monetary policy shocks.

This result also holds once capital is reintroduced and upon increasing the number of price-setting cohorts. In fact, Chari *et al.* (2000) find that the output persistence problem is actually worsened through the introduction of intertemporal links in capital accumulation and interest-sensitive money demand.

## 4.3. CRITICISMS AND ALTERNATIVE SPECIFICATIONS OF THE STICKY PRICE MODEL

As the previous analysis demonstrated, the basic sticky price model of Chari *et al*. (2000) is incapable of reproducing the desired output persistence. This is a surprising result, as the use of sticky prices was in fact motivated by the observation of persistent fluctuations in real output. Thus, it is necessary to examine alternative specifications designed to overcome, or al least ease, the output persistence problem. Some of the suggestions in the literature, which shall be examined in this section, are: the use of either near-perfect substitute preferences (Chari *et al*., 2000) or translog preferences (Bergin and Feenstra, 2000) rather than constant elasticity of substitution preferences; the inclusion of specific factors (Chari *et al*., 2000; Woodford, 2004; Huang 2006; Nolan and Thoenissen, 2008); the incorporation of an input-output structure (Bergin and Feenstra, 2000; Huang and Liu, 2001); and the use of price-setting rules that are not time dependent (Kiley, 2000).

### *4.3.1. Functional Form*

In their analysis, Chari *et al*. (2000) initially assume a constant elasticity of substitution (CES) form for the consumers' utility function, as this is the standard specification in the business cycle literature. However, although this is favourable in the sense that the CES form is consistent with a balanced growth path,[3] the CES specification implies that costs are extremely sensitive to output, and furthermore with constant elasticity of demand, price move one-for-one with costs.

Thus, this form dictates a price-setting rule that is simply a constant mark-up over marginal cost, rather than prices being set in response to competitors prices as Taylor (1980) intended (Bergin and Feenstra, 2000). As such, monetary shocks do not have persistent effects on output since as soon as the last contract period is complete, the aggregate price level has fully adjusted and all real effects of the shock disappear.

[3] See the work of Cooley and Prescott (1995)

Alternative specifications that should improve the model's ability to generate persistent output fluctuations include near-perfect substitute preferences (Chari *et al*., 2000) and translog preferences (Bergin and Feenstra, 2000).

*(a) Near-Perfect Substitute Preferences*

Assuming preferences where consumption and leisure are near-perfect substitutes (NPS) implies prices are insensitive to movements in marginal costs. Incorporating such a specification in the benchmark sticky price model implies a small γ in the price-setting equation (4.18), and consequently that the model should be capable of generating significant persistence.

A typical utility function of this type would take the following form:

$$U\left(c,l,\frac{M}{\overline{P}}\right)=\frac{1}{1-\sigma}\left[\frac{c^{1-\kappa}}{1-\kappa}-\omega_1\frac{l^{1+\zeta}}{1+\zeta}+\frac{\left(M/\overline{P}\right)^{1-\nu}}{1-\nu}\right]^{1-\sigma} \tag{4.23}$$

where, $1/\kappa$, $1/\zeta$ and $1/\upsilon$ are the elasticities of consumption, labour supply and money demand, respectively; and σ is risk aversion.

Chari *et al*. (2000) incorporate (4.23) in the benchmark sticky price model. Given this specification, they solve for γ,[4] with the solution:

$$\gamma=\kappa+\zeta \tag{4.24}$$

Thus if κ and ζ are small,[5] γ is also small. This implies that, from equation (4.18), large movements in output have small effects on the price level, which satisfies the condition in the money demand equation (4.16), namely that large movements in output in response to movements in money, requires small movements in the price level. Most importantly, γ is no-longer restricted to being greater than one, as in the CES case. Thus, the sticky price model with this specification is capable of generating persistent movements in output in response to monetary shocks; a value of γ of less than one implies a positive value of $a$ in (4.22).

In the quantitative analysis, Chari *et al*. (2000) find that this specification does indeed enable the model to generate significant output persistence, when abstracting from

[4] By log-linearising the labour supply equation

[5] Such an assumption implies that the utility function is close to linear in both consumption and leisure.

capital. However, once intertemporal links in either capital accumulation or interest-sensitive money demand are introduced, the model is once again incapable of generating persistent fluctuations in output. In fact with both intertemporal links in capital and money, movements in output do not even persist until all of the price contracts have been renewed. Interestingly, in the model with no intertemporal capital or money links, increasing the number of price-setting cohorts significantly increases the degree of output persistence, whilst with intertemporal links in both capital and money, increasing the number of price-setting cohorts significantly reduces the degree of output persistence.

*(b) Translog Preferences*

Under the assumption of translog preferences, the endogenous price setting rule is significantly influenced by competitors' prices and is no longer just a simple mark-up over marginal cost, as it is with CES preferences. This interaction suggests that when a shock hits the economy, firms will be inclined to wait and see how their competitors respond, before changing their own price; thus this should result in significant endogenous price stickiness.

Bergin and Feenstra (2000) incorporate translog preferences in a model very similar to the benchmark sticky price model of Chari *et al*. (2000). In this case, the utility function takes the form:

$$U\left(c,l,\frac{M}{\overline{P}}\right)=\left[\ln(c)-\frac{l^{1+\zeta}}{1+\zeta}+\ln\left(\frac{M}{\overline{P}}\right)\right] \tag{4.25}$$

Analytically, they find that the model with translog preferences yields the same solution as in the CES case, except that:

$$a=\frac{\sqrt{2}-\sqrt{\gamma}}{\sqrt{2}+\sqrt{\gamma}} \tag{4.26}$$

This definition of $a$ is somewhat less restrictive than in the CES case, as output persistence now requires that γ is less than two, rather than less than unity. Thus, with reasonable parameter values, this specification of the sticky price model should be able to generate significant output persistence.

Bergin and Feenstra (2000) perform simulations of the model with both CES and translog preferences, and two cohorts of price setters, defining endogenous persistence as "*the fraction of the initial impact that still persists two periods after the shock, when the remaining firms have also responded to the shock*" (p.671). With the CES specification, once all price contracts have been renewed output is 0.07% below its steady state value and thus, as expected, this specification is incapable of generating any endogenous persistence. Similarly the basic model with translog preferences is incapable of generating any endogenous persistence; output returns to its steady state level as soon as all contracts are renewed.

However, the incorporation of a simple input-output structure, in which an aggregate of the differentiated products serves as both the final consumption good and as an input in firms' production, significantly improves the model's ability to generate endogenous persistence. With translog preferences and a 0.9 share of the aggregate product in marginal costs, output remains at 50% above its steady state level after all firms have reset prices. The equivalent case with CES preferences yields output 37% above its steady state level once all firms have reset prices. The input-output structure acts to make firms increasingly sensitive to their competitors' prices, and consequently the combination of translog preferences and an input-output structure appear to be mutually reinforcing. Significantly, Bergin and Feenstra (2000) find that the introduction of capital in the model, except in the specification of CES preferences and no input-output structure, does not significantly reduce the degree of persistence generated.

From the work on translog preferences, it seems that one way to increase output persistence is to make prices less sensitive to changes in cost. Other suggestions to make prices less sensitive to cost changes include making demand for intermediate goods more convex (Kimball, 1995) and having firms employ inelastically supplied specific factors (Rotemberg, 1996). Chari *et al*. (2000) try incorporating both of these specifications in their benchmark sticky price model, with the finding that whilst they result in some significant output persistence when abstracting from capital. When reintroducing intertemporal capital and money links, however, the degree of output persistence is once again rendered insignificant. However, the incorporation of an input-output structure, such that prices are significantly influenced by their competitors' prices, does appear to be a promising avenue for generating significant endogenous output persistence.

### *4.3.2. Input-Output Structure*

In the basic sticky price model, Chari *et al*. (2000) assume that intermediate goods are produced using capital and labour inputs, whilst final goods are produced solely from intermediate goods. However, it is much more realistic to assume that all producers use a combination of capital, labour and intermediate inputs, thus requiring some form of input-output structure in the economy.

Bergin and Feenstra (2000) demonstrated that simply introducing an aggregate of the differentiated products as an input in firms' production significantly increased the degree of endogenous output persistence. To incorporate such a structure in the Chari *et al.* (2000) model, it is simply necessary to allow intermediate producers to use intermediate goods as inputs in addition to capital and labour. The production function for the intermediate producers then becomes:

$$y(i,s^t)=\left[F\left(z(i,s^t)\right)\right]^{\phi}\left[F\left(k(i,s^t),l(i,s^t)\right)\right]^{1-\phi}=\left(z(i,s^t)\right)^{\phi}\left(k(i,s^t)^{\alpha}\,l(i,s^t)^{1-\alpha}\right)^{1-\phi} \quad (4.27)$$

where, $z(i,s^t)$ is the intermediate input and ϕ is the intermediate input share.

This is similar to the specification used by Huang *et al.* (2000) and Huang and Liu (2004) to investigate the persistent real effect of a monetary policy shock under both wage and price staggering. Abstracting from capital, Huang and Liu (2004) solve for γ and the solution, considering just the price setting version of the model, is:

$$\gamma=\frac{(\xi_c+\xi_l)(1-\phi)}{1+f(\phi,\theta_x)\xi_l} \quad (4.28)$$

where, $f(\phi,\theta_x)=\dfrac{\phi}{\phi+\theta_x(1-\phi)}$, and $\xi_c=-CU''/U'$ and $\xi_l=-LV''/V'$ denote the steady state relative risk aversion in consumption and labour hours respectively, given the separable utility function $U(c,M/\bar{P})+V(l)$. The solution for $a$ is the same as for the benchmark sticky price model.

The inclusion of the input-output structure in the benchmark sticky price model, results in γ becoming a decreasing function of the intermediate input share ϕ; as ϕ→1, γ→0. This means that it is possible to obtain values of γ that are less than unity, and consequently that the model is capable of generating persistent movements of output in response to monetary shocks. As in Bergin and Feenstra (2000), Huang *et al.* (2000) find that the introduction of intertemporal capital accumulation and money demand in the model does not significantly reduce the degree of persistence generated.

Huang and Liu (2001) extend this intuition to a much more sophisticated production chain approach. They propose a model incorporating a vertical input-output structure, in which the production of a final consumption good goes through several stages of production, with goods at each stage requiring inputs of both labour and goods produced at the previous stage. Firms at each stage are imperfectly competitive in their output market, and set prices in a staggered fashion. Intuitively, this chain of production method seems to have the potential to generate significant output persistence;

> "*In a model with a single stage of production (and thus without the vertical input–output structure), prices adjust quickly and there is no real effect of money beyond the initial contract duration (e.g., Chari et al., 2000). This is so because the shock leads to a quick change in the wage rate and hence in the marginal cost for all firms. In our model with multiple stages of production, firms at more advanced stages of processing face smaller changes in their marginal cost and thus have smaller incentives to change their prices than do firms at less advanced stages. Consequently, movements in prices are dampened through the production chain and the response of aggregate output dies out gradually*" (Huang and Liu, 2001, p.440)

Huang and Liu (2001) find that the greater the number of production stages and the greater the share of intermediate inputs in production, the more persistent the response of output to monetary shocks. With sufficiently many stages of production, Huang and Liu (2001; p.457) calculate the following persistence measure:

*In the perfect foresight equilibrium, the equality*

$$\lim_{S\to\infty} y_S(t) = \frac{(1+\beta)\rho}{2(1+\beta)-(1+\beta\rho)\phi} \tag{4.29}$$

*holds for all t≥0, where*

$$\rho = \frac{(1+\beta)(2-\phi)-\sqrt{(1+\beta)^2(2-\phi)^2-4\beta\phi^2}}{2\beta\phi} \tag{4.30}$$

where, S is the number of production stages and ρ is the persistence measure.[6]

Significantly this implies that with sufficiently many production stages (S→∞), the persistence measure will goes to unity (ρ→1) as the share of intermediate inputs goes to unity (ϕ→1). Thus, although empirically infeasible, with ϕ=1 it is possible to "*obtain arbitrary real persistence in the sense that the price level does not change and aggregate output carries the full burden of adjustment*" Huang and Liu (2001, p.457).

Furthermore, this is the first model to provide a mechanism by which it is possible to represent the business cycles of countries at different levels of development; Basu (1995), for example, has shown that input-output structure tend to be much more sophisticated in

[6] These parameters have been changed from those in the Huang and Liu (2001) paper, in order to maintain consistency with the rest of this chapter. In the paper, N is the number of production stages, γ is the intermediate input share and ξ is the persistence measure.

developed than developing countries. Therefore, simply by changing the number of stages of production in the input-output structure it should be possible to represent not only the simplest of economies, but also the most sophisticated, and everything in-between.

### *4.3.3. Specific Factors*

Assuming goods are produced from capital that is endogenous and firm specific, as suggested by Woodford (2005), implies that the firm's marginal cost of supplying a good depends on both the quantity of goods produced during a period and on the firm's capital stock. This provides a potential source of endogenous persistence, because the capital stock depends on decisions made by the firm in previous periods, including its previous pricing decisions.

Chari *et al.* (2000) consider the impact of specific factors on the benchmark sticky price model through the incorporation of a specific factor, in addition to capital and labour, that is used in the production of intermediate goods. They find that with the inclusion of specific factors, the sensitivity of firms' prices to changes in aggregate output is affected by an additional wage effect, which acts to make prices less sensitive to changes in output. Significantly, "*when demand is sufficiently elastic, the wage effect dominates, the monopolist's price is relatively insensitive to aggregate output, and monetary shocks have more persistent effects*" (Chari *et al.*, 2000, p.1171).

In the absence of intertemporal links, the solution for $\gamma$ in the price setting equation (4.18) becomes:

$$\gamma = \frac{(1+A)+(\theta_x \omega / \psi)}{(1+A\varepsilon)} \tag{4.31}$$

where, $A = \alpha / (1-\alpha)$ and $\varepsilon = 1/(1-\theta_x)$ is the elasticity of demand.

Thus, Chari *et al.* (2000) are able to show that as the elasticity of demand increases, the value of $\gamma$ decreases, and furthermore with sufficiently large elasticity, $\gamma$ goes to zero and output persistence is infinite. However, upon the reintroduction of intertemporal links in money and capital, the model with specific factors is unable to generate significantly more output persistence that the benchmark model.

Huang (2006) considers a sticky price model with both specific factors and a basic input-output structure, to examine whether this combination is the key to generating significantly persistent output fluctuations in response to monetary shocks. Both mechanisms are intuitively appealing. The input-output structure acts to impede the response of marginal cost, and thus to slow price changes and increase persistence. Specific factors act to dampen movements in the prices of factors and goods; demand for a specific factor depends on the demand for the firm's output and the relative price of this output, which in turn depends on the price of the specific factor. Any increase in factor price will increase output price, reducing demand for the output and consequently demand for the specific factor. It is this negative feedback that dampens price movements and hence increases persistence. However, Huang (2006) discovers that the two mechanisms effectively counteract each other, resulting in little or no persistence as in the benchmark case.

Abstracting from capital so the only specificity is labour, assuming there are only two cohorts of price setters (N=2) and solving for $a$ in the persistence equation (4.22), Huang (2006) obtains:

$$a = \frac{1-\sqrt{\Gamma}}{1+\sqrt{\Gamma}} \tag{4.32}$$

$$\Gamma = (1-\phi)\left(\frac{\xi_c}{\xi_l}+1\right)\left(\frac{1}{\xi_l}+\frac{e\phi}{\phi+\theta_x(1-\phi)}\right)^{-1}\left(1+\frac{\theta_x(1-\phi)}{\xi_l^{-1}+e\phi}\right)^{-1} \tag{4.33}$$

where, Γ determines the firm's desired relative price change it variations in real income or real aggregate demand, ϕ is the share of intermediate inputs in production, $\theta_x \in [1,\infty]$ and $e \in [1,\infty)$ are the elasticities of substitution between individually differentiated goods and between primary factors and the intermediate inputs respectively; and $\xi_c = -CU''/U'$ and $\xi_l = -LV''/V'$ denote the steady state relative risk aversion in consumption and labour hours respectively, given the separable utility function $U(c, M/\bar{P}) + V(l)$.

As previously, the persistence of output depends critically on the value of $a$ and hence Γ; the smaller the value of Γ, the greater the value of $a$ and consequently the more persistent the response of output. The necessary condition for this specification to generate significant endogenous output persistence is Γ < 1, such that $a \in (0,1)$, otherwise if Γ is greater than one, $a$ is negative and the model is incapable of generating any endogenous persistence, as in case of the benchmark sticky price model.

In the absence of labour specificities, (4.33) reduces to (4.28) and Γ is a decreasing function in ϕ (as ϕ→1, Γ→0), and therefore that the input share is positively related to persistence. On the other hand, with labour specificities and no input-output structure, (4.33) reduces to:

$$\Gamma = \frac{\xi_l + \xi_c}{1 + \theta_x \xi_l} \tag{4.34}$$

which implies that Γ is a increasing function of the labour supply elasticity ($1/\xi_l$) and a decreasing function of the elasticity of substitution between differentiated goods ($\theta_x$); therefore the smaller is $1/\xi_l$ and the larger is $\theta_x$, the greater the persistence.

However, now considering the full model, the two specifications actually act to weaken one another's persistence generating mechanisms. This negative interaction is embodied in the final term of equation (4.33).

With labour specificities, the demand for labour depends directly on the demand for firms' output, which depends on the relative price of said output and hence, as it is a component of marginal cost, on the real wage. However, the use of intermediate inputs reduces the impact of an increase in real wage on the firms marginal cost, and thus weakens the role of the specific factors in generating persistence. And as Huang (2006) notes:

> "*the response of the firm's desired price to a given movement in the real wage is attenuated by a factor of ϕ and so is the counter-forcing shift in the labour demand schedule by labour specificities*" (p.493)

Secondly, as $\phi \to 1$ labour demand becomes more elastic inducing smaller wage adjustments in response to shifts in labour demand. In the absence of specific factors, this leads to more persistence. However, with specific factors, this weakens the negative feedback mechanism that is key to generating persistence in the specific factor model.

Huang (2006) finds that the negative interaction between these two mechanisms is so strong that it dominates the individually promising effects. Consequently, with labour specificities, the impact of increasing ϕ actually acts to increase Γ, through the final term of equation (4.33), and thus to reduce persistence.

### *4.3.4. Price-Setting Rules*

A major bugbear in the literature has been the use of time dependent price setting rules, as used by Chari *et al*. (2000). Although analytically convenient, time-dependent price setting rules constrain firms to change prices only at pre-specified times, between which firms are not allowed to respond even to extreme changes of circumstances. This makes it difficult to know whether the qualitative effects of money in these models are the result of the nominal rigidities per se or the exogenously imposed pattern of price changes (Caplin and Leahy, 1991).

An alternative then is to allow the price setting decision to depend on the actual state of the economy, with firms discretely changing their prices each time they deviate a certain amount form their optimal value. However, in order to generate significant persistence state-dependent pricing requires the incorporation of adjustment costs and imperfect, or sticky, information.

Kiley (2000), for example, assumes a fixed cost of adjusting prices such that firms find it sub-optimal to continually adjust nominal prices. This should mean that prices respond slowly to shocks, with output fluctuations persisting until the price adjustment is complete. Kiley (2000) develops a model which combines price adjustment costs and information acquisition costs in order to examine the persistence of output fluctuations in response to nominal aggregate demand disturbances; although such an approach could easily be used to similarly examine monetary shocks. Under perfect information, the optimal adjustment policy would be a state-dependent rule where the probability of adjustment in any period depends on the size of the deviation from the desired price; this is a Calvo (1983) type pricing rule. However, in order to generate significant persistent effects, Kiley (2000) also assumes that the acquisition of information about optimal prices is costly. As such, some firms will be unaware of any aggregate demand shocks affecting the economy and consequently will simply allow output to adjust rather than adjusting prices.

Assuming that demand and supply shocks in the Kiley (2000) model have no persistence, the persistence of real output in response to a shock is determined solely by the probability of firms changing prices (φ). Consequently, to increase persistence it is necessary only to reduce the probability of changing prices:

$$y_t = (1-\varphi)y_{t-1} + (1-\varphi\Theta)\Delta n_t + e_t \tag{4.35}$$

where, Θ is the number of firms that purchase information, $n_t$ is nominal output and $e_t$ is the supply shock.

Interestingly, this implies that output fluctuations should be less persistent in countries with higher inflation and hence a higher probability of changing prices. Kiley (2000) proceeds to empirically test this implication, finding that output fluctuations tend to be less persistent in high inflation countries.

An alternative to costly information is sticky information or a gradual learning process, as suggested by Dellas (2006), whereby information disseminates slowly throughout the population. The incorporation of imperfect information, either through costs or gradual learning, is a promising mechanism to explain both output persistence and the observed inertial behaviour of inflation.

## 4.4. THE EQUIVALENCE OF STICKY PRICES AND WAGES

Conventional wisdom, following Taylor (1980), suggests that staggered price and wage setting should have similar implications for the dynamics of aggregate output and the price level. However, important work by Huang and Liu (2002, 2004) scrutinized this equivalence, finding staggered price and wage setting to have quite different implications for persistence. Thus, they suggest an alternative specification incorporating sticky wages.

### *4.4.1. Sticky Wages*

In order to incorporate sticky wages into the basic sticky price model, it is necessary to make the labour market imperfectly competitive. Following Huang and Liu (2002, 2004), households are assumed to be price takers in the final goods market and monopolists in the labour market. Each household is endowed with a differentiated labour skill $j \in [0,1]$, and in each period t, upon the realisation of event $s_t$, $1/N_W$ of the households can choose new wages. Once set, these wages remain effective for $N_W$ periods.

The optimal choice of nominal wage for household j, at time t, is give by:

$$w\left(j,s^t\right)=\frac{\theta_l}{\theta_l-1}\frac{\sum_{\tau=t}^{t+N_W-1}\sum_{s^\tau}Q\left(s^\tau\left|s^t\right.\right)l^d\left(j,s^t\right)\left[-U_l\left(j,s^t\right)/U_c\left(j,s^t\right)\right]\bar{P}\left(s^\tau\right)}{\sum_{\tau=t}^{t+N_W-1}\sum_{s^\tau}Q\left(s^\tau\left|s^t\right.\right)l^d\left(j,s^t\right)} \quad (4.36)$$

where, $\theta_l > 1$ is the elasticity of substitution between differentiated labour skills, whilst $U_L\left(j,s^t\right)$ and $U_c\left(j,s^t\right)$ denote the marginal utility of leisure and consumption respectively.

### *4.4.2. Output Persistence under Sticky Prices and Sticky Wages*

The persistence implications of price and wage staggering are embodied in the price and wage setting equations. Following the analytics of Huang and Liu (2002, 2004), log-linearising the decision rules and assuming a discount factor of unity, yields the following price and wage setting equations:

$$p_t = \sum_{j=1}^{N_P-1} b_j p_{t-j} + \mathbf{E}_t \sum_{j=1}^{N_P-1} b_j p_{t+j} + \frac{\gamma_P}{N_P - 1} \mathbf{E}_t \left( y_{t+j} \right) \quad (4.37)$$

$$w_t = \sum_{j=1}^{N_W-1} b_j w_{t-j} + \mathbf{E}_t \sum_{j=1}^{N_W-1} b_j w_{t+j} + \frac{\gamma_W}{N_W - 1} \mathbf{E}_t \left( y_{t+j} \right) \quad (4.38)$$

where, $b_j = [N - j] / [N(N-1)]$, $N_P, N_W$ are the number of price and wage setting cohorts respectively, and $\gamma_P, \gamma_W$ are the elasticities of relative price and wage respectively. Note that with two price setting cohorts, the price setting equation reduces to that of (4.18).

The first two terms of the price and wage setting equations imply that both firms and households would like to keep their prices (wages) in line with those set in the past and those expected to be set in the future. The distinction between price and wage staggering lies in the differences in the elasticities of relative price and wage, $\gamma_P$ and $\gamma_W$, with respect to future output. Huang and Liu (2002, 2004) find these parameters to be given by:

$$\gamma_P = \xi_c + \xi_l \quad (4.39)$$

$$\gamma_W = \frac{\left( \xi_c + \xi_l \right)}{1 + \theta_l \xi_l} \quad (4.40)$$

where, $\xi_c = -CU''/U' > 0$ and $\xi_l = -LV''/V' > 0$ denote the steady state relative risk aversion in consumption and labour hours respectively, given the separable utility function $U\left(c, M/\overline{P}\right) + V\left(l\right)$.

The amount of endogenous stickiness, and hence the amount of endogenous persistence, is inversely related to the magnitude of $\gamma_P$ and $\gamma_W$. The restrictions $\theta_l > 1$, $\xi_c > 0$ and $\xi_l > 0$ imply that $\gamma_W \leq \gamma_P$. Thus, whilst the price staggering mechanism, on its own, is incapable of generating any persistence beyond the initial contract duration, it appears that the wage staggering mechanism can potentially generate significant endogenous output persistence, depending of course on the associated parameter values. Anderson (1998) similarly finds that nominal shocks have a persistent effect on output in wage staggering models, but not in price staggering models.

### *4.4.3. Sticky Prices, Sticky Wages and Specific Factors*

Edge (2002) questions the findings of Anderson (1998) and Huang and Liu (2002), stating that

> "*the relative abilities of price and wage staggering to generate persistent real responses to monetary shocks rely heavily on these authors' assumptions concerning factor markets; specifically, that identical sets of inputs are used by all firms*" (p. 560).

Thus, Edge (2002) proceeds to examine the equivalency of the staggered wage model and the staggered price model with specific factors; the incorporation of specific factors in the staggered wage model is not considered. Since the previous section revealed that the distinction between price and wage staggering lies in the differences in $\gamma_P$ and $\gamma_W$, it is necessary to solve for these under the current specifications. Abstracting from capital, Edge (2002) obtains the following functions:

$$\gamma_P = \frac{1+\rho_{hh}}{1+\theta_x \rho_{hh}} \tag{4.41}$$

$$\gamma_W = \frac{1+\rho_{hh}}{1+\theta_l \rho_{hh}} \tag{4.42}$$

where, $\rho_{hh} > 0$ is the elasticity of labour substitution, and $\theta_x, \theta_l \geq 1$ are the elasticities of substitution between differentiated goods and differentiated labour inputs respectively.

Given the parameter constraints, it is obvious that both $\gamma_P$ and $\gamma_W$ are less than unity. This implies, given (4.20) and (4.22), that both model specifications are capable of generating persistent movements in output in response to monetary shocks. Furthermore, given the same parameter values for the elasticity of substitution between differentiated labour inputs ($\theta_l$) and between differentiated goods ($\theta_x$) the sticky price model with labour specificities can produce exactly the same magnitude of endogenous persistence as the sticky wage model.

However, this analysis ignores one vital point; these solutions have been obtained by abstracting from capital and once intertemporal links in capital and money are reintroduced to the specific factor sticky price model, this specification is unable to generate significantly more output persistence that the basic sticky price model. Thus, the previous result holds, namely that whilst the staggered wage model is capable of generating significant output persistence, the staggered price model is not.

### *4.4.4. Sticky Prices, Sticky Wages and an Input-Output Structure*

Huang and Liu (2004) revisit their work on the equivalence of staggered price and wage setting. They find that the inclusion of an input-output structure in the model tends to make staggered price setting an equally important, if not more, important mechanism for generating endogenous persistence than staggered wage setting.

The intermediate share ϕ enters $\gamma_P$ and $\gamma_W$ in different ways, implying that the incorporation of an input-output structure will interact with staggered price and wage setting differently. Huang and Liu (2004) find the values of $\gamma_P$ and $\gamma_W$ to be given by:

$$\gamma_P = \frac{(\xi_c + \xi_l)(1-\phi)}{1 + f(\phi, \theta_x)\xi_l} \tag{4.43}$$

$$\gamma_W = \frac{(\xi_c + \xi_l)}{1 + \theta_l \xi_l} \tag{4.44}$$

where, $f(\phi,\theta_x) = \phi/[\phi + \theta_x(1-\phi)]$, $\theta_x, \theta_l \geq 1$, and $\xi_c, \xi_l > 0$.

Since $\gamma_P$ is decreasing in ϕ, the introduction of an input-output structure significantly improves the ability of the staggered price model to generate output persistence, as discussed in section 4.3.3. However, since $\gamma_W$ is independent of ϕ, the input-output structure does not help staggered wage setting to generate any additional endogenous output persistence beyond what is already implied.

This has important implications for the specification of models. In the absence of the input-output structure, such that ϕ = 0, the staggered wage mechanism appears to be much more successful in generating endogenous output persistence. However, upon the introduction of an input-output structure, such that 0 < ϕ < 1, this ordering is reversed and the staggered price mechanism becomes the more successful option for generating significant endogenous output persistence. This is summarised in Table 4.1.

**Table 4.1 Importance of the Intermediate Input Share**

| Intermediate Input Share | Order of Persistence |
|---|---|
| $\phi = 0$ | $\gamma_P > \gamma_W$ |
| $0 < \phi < 1$ | $\gamma_P \leq \gamma_W$ |
| $\phi \rightarrow 1$ | $\gamma_P \rightarrow 0$ |

## 4.5. CONSEQUENCES OF AN EXPANSIONARY MONETARY SHOCK

The output persistence problem stems from the inability of the basic sticky price model to generate persistent output fluctuations in response to monetary policy shocks, without staggered prices that are set for exogenously long periods of time. Thus far, this chapter has discussed the reasons for this failure and the success of the suggested model modifications from a purely analytical perspective. In light of this analysis, the dynamic responses of aggregate variables, particularly real output and the real wage, to an expansionary monetary policy shock are examined under various specifications of the model.

### *4.5.1. Sticky Prices and Wages*

Under staggered price setting, aggregate output initially rises in response to an expansionary monetary policy shock; however, this effect is not persistent. The increase in aggregate demand, resulting from the shock, causes the demand for labour at any given wage to increase. This raises the marginal utility of leisure whilst the additional income causes the marginal utility of consumption to fall, the combined effect inducing consumers to raise their nominal wage. Thus, given synchronised wage setting, the real wage increases. Now, with no input-output mechanism, and assuming CES preferences, firms' marginal costs depend solely on the wage rate and the cost of capital. Increases in the real wage therefore directly increase firms' marginal costs. Firms respond by increasing their prices as soon as they can renew their contracts, and thus aggregate output returns to its steady-state level as soon as the final cohort has adjusted its prices.

The model with staggered wage setting, however, does produce significant output persistence; after the initial increase, aggregate output only slowly returns to its steady-state level. As before, the monetary shock transmits into a higher demand for labour inducing consumers to increase their wage rates as soon as they can renew their contracts. However, with staggered wage setting, an increase in a consumers' nominal wage will lead to an increase in its relative wage. Thus, firms will choose to employ the relatively cheaper workers who have yet to adjust their wage rates. This acts to discourage consumers' from raising their wages by too much. Hence, firms only have to raise their prices slightly and thus aggregate output returns to its steady-state only gradually.

Under both staggered price and wage setting, the model produces procyclical movements in consumption, investment and employment. Furthermore, consistent with empirical evidence, investment is found to be more volatile than output, which in turn is more volatile than consumption. However, the two staggering mechanisms differ in their predicted responses of the real wage.

The persistence of output, or lack of, and the movement of the other aggregate variables in response to an expansionary monetary policy shock under the staggered price and staggered wage setting specifications are clearly illustrated by the impulse response functions reported in Huang and Liu (2002); reproduced here as Figures 4.1 and 4.2.

Thus, as Huang and Liu (2002) discuss, there are two key differences between the responses of the models under staggered price setting and under staggered wage setting. Firstly, under staggered wage setting the impulse responses of both real and nominal variables are much more persistent than under staggered price setting. Secondly, under staggered price setting the real wage is strongly procyclical, whereas under staggered wage setting it is weakly countercyclical; strongly procyclical real wages are more consistent with those observed in both developed and developing countries in recent years (see chapter 3).

### *4.5.2. Sticky Prices, Sticky Wages and a simple Input-Output Structure*

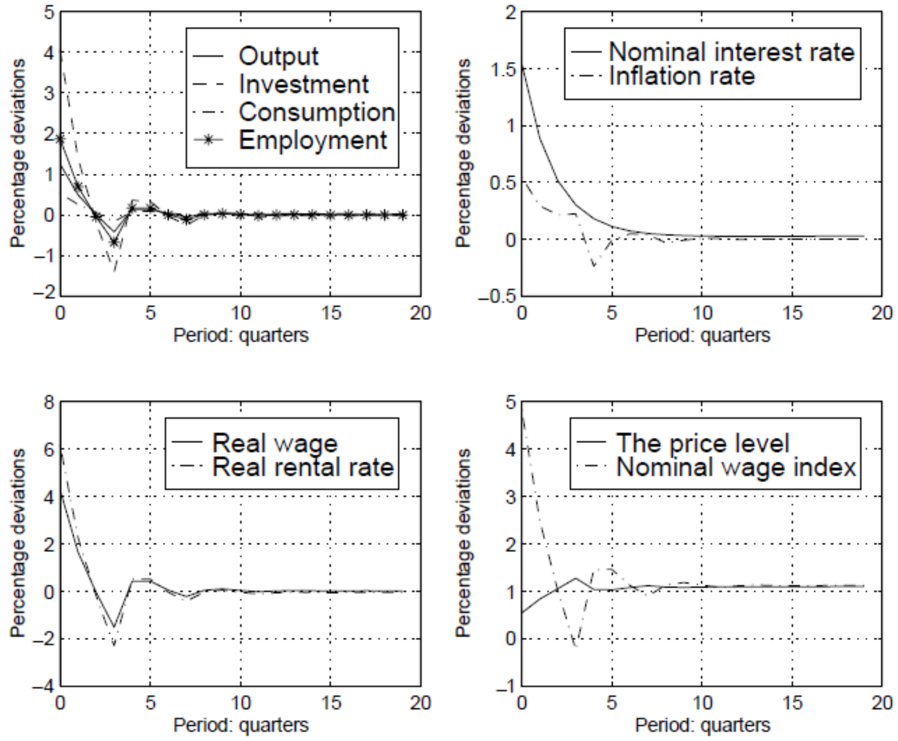
From the discussion in section 4.4.2, it is anticipated that the introduction of a simple input-output structure will have a significant effect on the output persistence generated under sticky prices, but will have no effect on the sticky wage model. $\gamma_W$ is independent of $\phi$, thus the input-output structure does not help staggered wage setting to generate any additional endogenous output persistence beyond what is already implied.

A basic input-output structure, following Huang *et al.* (2000), is considered, whereby intermediate producers use intermediate goods as inputs in addition to capital and labour. The incorporation of such a mechanism makes output prices an important component of marginal costs which, under staggered price setting, has a significant impact on the persistence of aggregate output following a monetary shock.

As in the benchmark sticky price model, the expansionary shock increases aggregate demand and hence the demand for labour at any given wage. This, in turn, raises the marginal utility of leisure whilst the additional income causes the marginal utility of consumption to fall, the combined effect inducing consumers to raise their nominal wage.

**Figure 4.1**

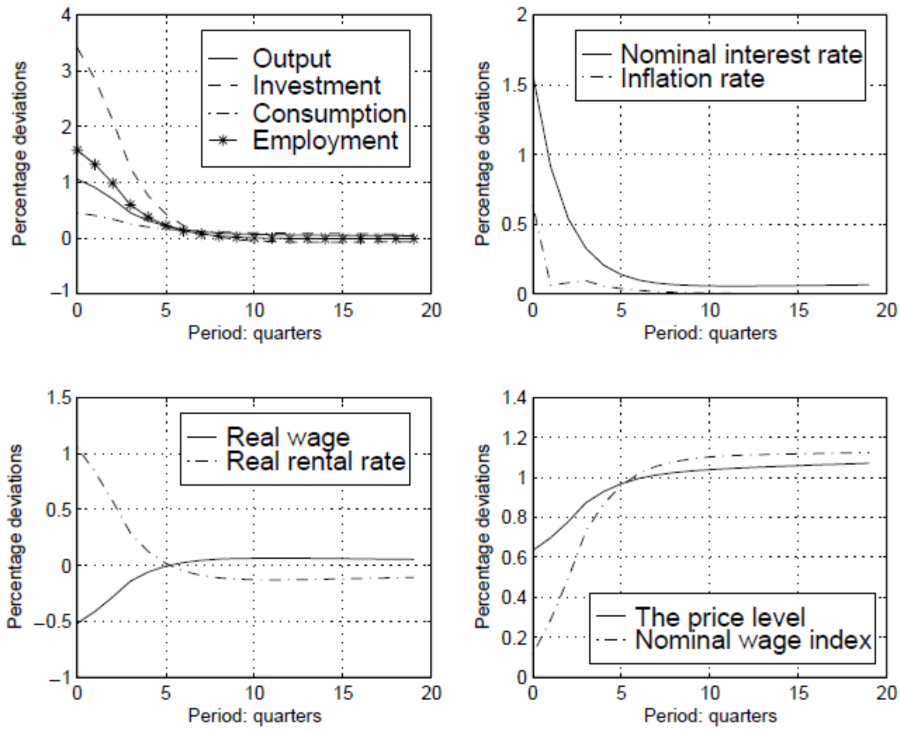
**Impulse Responses of the Sticky Price Model to a 1% Expansionary Monetary Policy Shock**




Huang and Liu (2002, p.426; Figure3)

**Figure 4.2**

**Impulse Responses of the Sticky Wage Model to a 1% Expansionary Monetary Policy Shock**




Huang and Liu (2002, p.425; Figure2)

Thus, given synchronised wage setting, the real wage increases. However, the introduction of the input-output structure means that firms, facing an increase in the real wage rate, will have an incentive to substitute away from labour inputs in favour of the relatively cheaper intermediate goods. However, as in the staggered wage case, this acts to discourage consumers' from raising their wages by too much. Thus, price adjustment becomes more sluggish and the response of output becomes more persistent.

Since, the input-output structure induces sluggish price movements, and hence output persistence, by discouraging consumers' from raising their wages, as in the staggered wage model, it follows intuitively that incorporating sticky wages into a model with sticky-prices and an input-output should help to increase the degree of endogenous persistence generated.

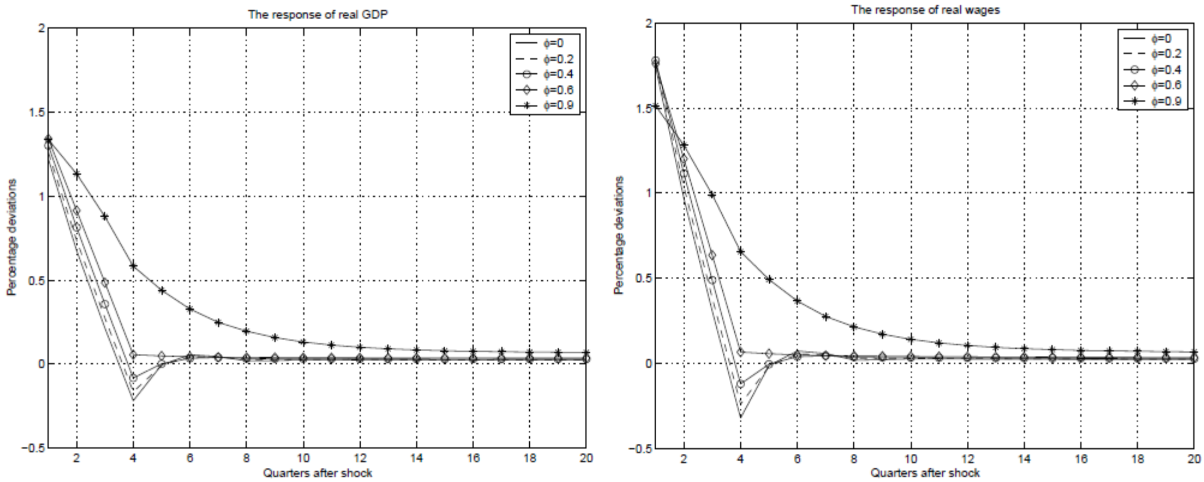
Huang *et al.* (2000) consider the impact of an expansionary monetary policy shock on real GDP and real wages for the model with sticky prices and the basic input-output structure, with sticky wages and the basic input-output structure, and with both sticky prices and sticky wages and the input-output structure. Furthermore, the importance of the share of intermediate inputs in production ($\phi$) on persistence is considered. Figures 4.3, 4.4 and 4.5 report the impulse responses detailed in Huang *et al.* (2000).

From the impulse responses in Figure 4.3, it is obvious that increasing the importance of the input-output structure, by increasing $\phi$, increases output persistence in the sticky price model. However, for a significant increase in persistence it is necessary to have a very large share of intermediate inputs in production ($\phi = 0.9$). The real wage is procyclical, as predicted, regardless of the intermediate share.

As expected, Figure 4.4 demonstrates that the incorporation of the input-output structure has no tangible effect on the impulse responses of either real output or the real wage in the sticky wage model, with the latter remaining countercyclical whatever the intermediate share.

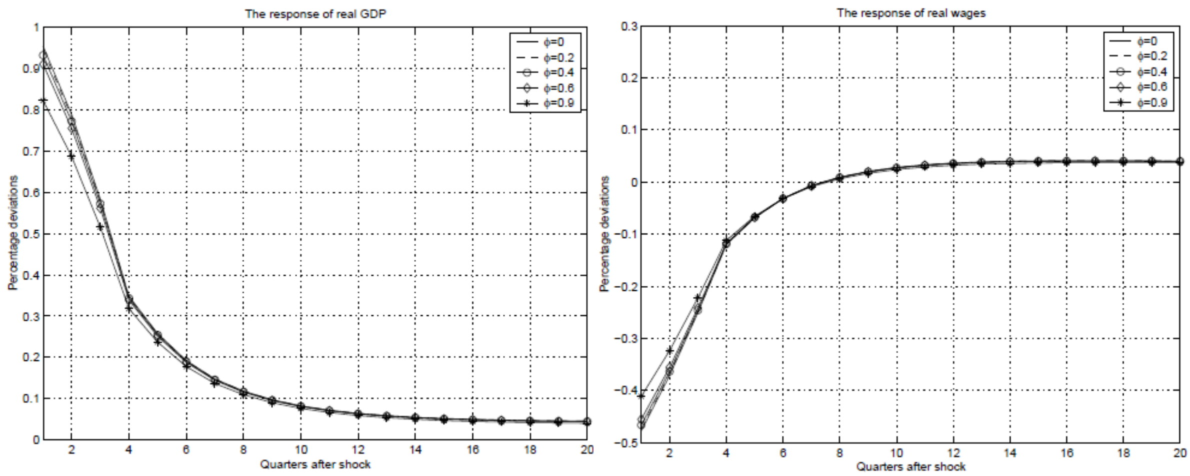
Subsequently, the impulse responses of the model with both staggered price and wage setting, as shown in Figure 4.5, are examined. In the simplest case, ignoring the input-output structure ($\phi$=0), the model generates output persistence and weakly countercyclical real wages consistent with the staggered wage model. However, as the share of intermediate inputs increases ($\phi \rightarrow 1$), not only does output persistence increase but also the real wage response changes from being countercyclical, to being acyclical, to being weakly procyclical.

**Figure 4.3 Impulse Responses of the Sticky Price Model with an Input-Output Structure to a 1% Expansionary Monetary Policy Shock**



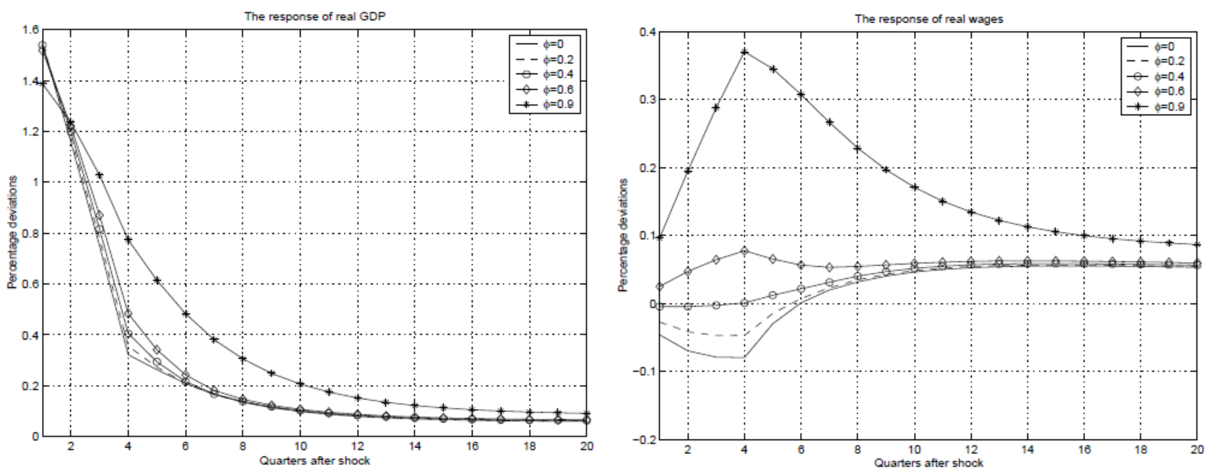

Huang *et al.* (2000, Figure 1)

**Figure 4.4 Impulse Responses of the Sticky Wage Model with an Input-Output Structure to a 1% Expansionary Monetary Policy Shock**




*Huang et al.* (2000, Figure 2)

**Figure 4.5 Impulse Responses of the Sticky Price and Sticky Wage Model with an Input-Output Structure to a 1% Expansionary Monetary Policy Shock**




Huang *et al.* (2000, Figure 3)

This is consistent with empirical evidence documented by Basu and Taylor (1999), amongst others, which suggests that the real wage has become increasingly procyclical in recent years as input-output connections have advanced, whilst being countercyclical in the Nineteenth Century and acyclical in the early Twentieth Century. Thus, this model is able to both generate significant endogenous output persistence and provide a potential explanation for the observed cyclicality of the real wage (Huang and Liu, 2004).

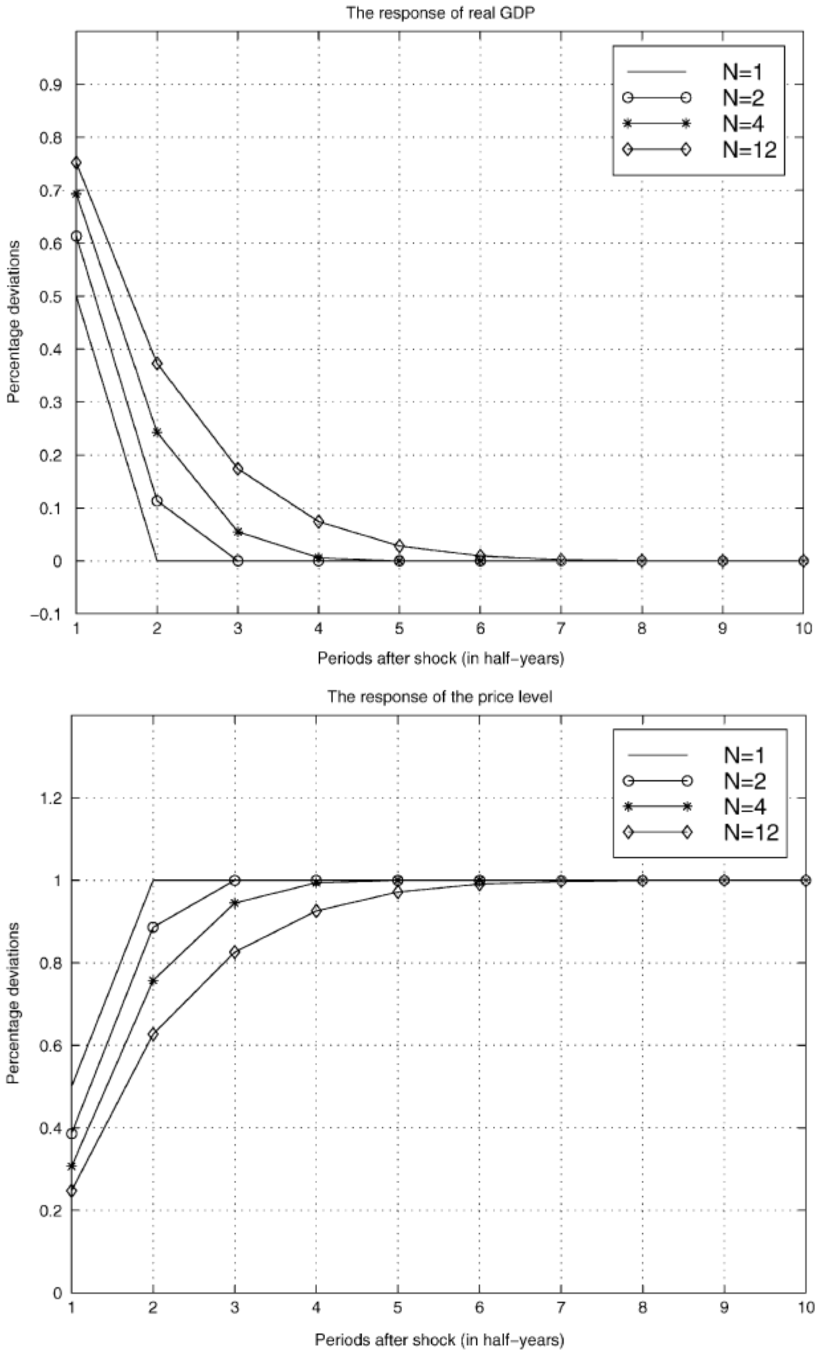
### *4.5.3. Sticky Prices and a Vertical Production Chain*

The final specification considered here, is the sticky price model with a sophisticated vertical production chain, as proposed by Huang and Liu (2001). The incorporation of an input-output structure, as already discussed, enables the sticky price model to generate significant output persistence, and thus to begin to dispel the output persistence problem.

Intuitively, if there is only one stage of production, so that labour is the only input, then the real effect of the monetary shock will not last beyond the initial contract duration. Following the shock, wages and hence marginal cost increase immediately and consequently firms increase prices as soon as they can renew their contracts. In contrast, if there are several stages of production, the effect of the shock is extenuated through the production chain. Stage one firms experience a full rise in their marginal costs, as in the single stage model, and thus increase prices as soon as they can renew their contracts. However, due to the staggered nature of the stage one firms' price increases, the firms at stage two do not immediately endure a full marginal cost increase. Thus, stage two firms that are able to renew contracts during the initial period will not choose to raise prices fully. At the end of the initial period, when all stage one firms have renewed their contracts, the marginal cost at stage two will also fully adjust and the stage two firms will now choose to fully increase prices when it is time to renew their contracts. Correspondingly, firms at higher stages will face even smaller changes in their marginal cost and have even less of an incentive to adjust prices. Thus, as production chain length increases, movements in the price level decrease and fluctuations in aggregate output become increasingly persistence.

Figure 4.6 reports the impulse responses of real GDP and prices in the vertical production chain model to an expansionary monetary policy shock as computed by Huang and Liu (2001).

**Figure 4.6 Impulse Responses of Real GDP and Prices to a 1% Expansionary Monetary Policy Shock in the Vertical Production Chain Model**




Huang and Liu (2001, p.453; Figure 4)

Examination of Figure 4.6, reveals that increasing the number of production stages dramatically increases the persistence of real GDP. Furthermore, the pattern of price level responses to the expansionary monetary shock replicates those observed by Clark (1999), namely that:

> "*prices at early stages of production fall more rapidly and by a larger amount than prices at subsequent stages of production*" (pp.424-425).

However, Huang and Liu (2001) do not calibrate the number of stages of production, and therefore cannot say whether the model empirically matches the level of persistence observed.

## 4.6. CONCLUSIONS

Business cycles of both developed and developing countries are characterised by persistent output fluctuations, and thus this has received much theoretical interest. However, the construction of dynamic general equilibrium models capable of generating persistent output fluctuations in response to monetary policy shocks without staggered prices, or wages, that are set for exogenously long periods of time, has proved difficult. Thus, this is known as the output persistence problem.

The benchmark sticky price model of Chari et al (2000) fails to generate any output persistence beyond what is exogenously imposed by the price setting rule. Consequently there have been many suggestions in the literature as to how to improve this outcome. Adaptations such as the use of translog, rather than CES, preferences, the incorporation of a simple input-output structure, and the introduction of sticky information, are fairly successful in improving the model's ability to generate output persistence, though the magnitude of this persistence remains below that observed in the data. Others, such as the use of near-perfect substitute preferences or the incorporation specific factors, appear analytically promising. However, upon the reintroduction of intertemporal links in capital and money demand the degree of output persistence, beyond what is exogenously imposed, is once again rendered insignificant.

The alternative sticky price model is much more successful in generating significant output persistence, but produces real wages which are countercyclical, which is not consistent with the empirical evidence for either developed or developing countries. However, Huang and Liu (2004) find that the incorporation of an input-output structure in the model tends to make staggered price setting an equally, if not more, important mechanism for generating endogenous persistence than staggered wage setting. Thus, it is possible to generate significant output persistence and procyclical real wages.

However, the extent of the persistence is still limited. Thus, Huang and Liu (2001) extend the input-output mechanism to a vertical production chain structure, and prove that with sufficiently many production stages, as the share of intermediate inputs in production goes to unity, output persistence becomes infinite. Furthermore, the vertical production chain model of Huang and Liu (2001) provides a promising avenue for the investigation of the business cycles of economies at different levels of development. Since more stages of production can be added to represent more complex, or more developed economies, it should be possible to represent not only the simplest of economies, but also the most sophisticated, and everything in-between.

# CHAPTER 5

## *"Business Cycle Persistence in Developing Countries: Can a DSGE Model with Production Chains and Sticky Prices Reproduce the Stylised Facts?"*

### 5.1. INTRODUCTION

One of the central issues concerning macroeconomists in recent years has been the construction of dynamic general equilibrium models in which monetary policy shocks generate persistent output fluctuations without prices that are set for exogenously long periods. However, whilst much work has been carried out on modelling this empirical feature for the industrialised countries, little, if any, theoretical work has examined this in the context of developing country business cycles. Thus, this chapter aims to address this balance, by firstly examining the degree of output persistence in developing countries, and its relation to economic development. And secondly, through the use of a dynamic general equilibrium model in which monetary policy shocks are able to generate persistent output fluctuations in line with those observed for the developing countries.

Theoretical work on the issue of output persistence originates from the seminal papers of Taylor (1980) and Blanchard (1983) who examine output persistence in the context of staggered price and wage contracts. Their intuition is extended to a general equilibrium model in the influential work of Chari, Kehoe and McGrattan (2000). However, rather surprisingly, they find that a staggered price mechanism is, by itself, incapable of generating persistent output fluctuations beyond the exogenously imposed contract rigidity.

Thus, the need for an alternative specification of the sticky price model became apparent and a burgeoning literature emerged expressing the importance of input-output structures in the transmission of business cycle shock.[1] For example, Bergin and Feenstra (2000) combine the use of translog preferences, rather than the usual CES preferences, and a simple input-output production structure, as proposed by Basu (1995), where an aggregate of differentiated products serves as both the final consumption good and as an input into the production function of each firm. These two features interact in a positive

[1] Among other suggestions in the literature, including: the application of translog, rather than CES, preferences, e.g. Bergin and Feenstra (2000); the importance of wage staggering, e.g. Huang and Liu (2002); and the inclusion of firm specific capital, see Nolan and Thoenissen (2005) for example.

way and generate significant endogenous output persistence, although this level remains considerably below that observed in the data.

A significant advancement then arises from the vertical input-output mechanism of Huang and Liu (2001). This addresses not only the output persistence issue but also another interesting issue, which is not considered by the aforementioned papers, namely that, in response to a monetary policy shock:

> "*prices at early stages of production fall more rapidly and by a larger amount than prices at subsequent stages of production*" (Clark, 1999, pp.424-425)

In the Huang and Liu (2001) model, the production of a final consumption good involves multiple stages of processing and, in order to generate real effects of a monetary shock, prices are staggered among firms within each stage. The input-output structure is fashioned through producers, at all but the initial stage, requiring inputs of labour and a composite of goods produced at earlier stages. Through the input-output relations across stages and the staggered prices within stages, the model is capable of generating persistence output fluctuations in response to monetary policy shocks as well as replicating the observed pattern of dampening price adjustment, as documented by Clark (1999).

The intuition behind the model is as follows: if there is only one stage of production, so that labour is the only input, then the real effect of the monetary shock will not last beyond the initial contract duration. Following the shock, wages and hence marginal cost increase immediately and consequently firms increase prices as soon as they can renew their contracts. In contrast, if there are several stages of production, the effect of the shock is extenuated through the production chain. Stage one firms experience a full rise in their marginal costs, as in the single stage model, and thus increase prices as soon as they can renew their contracts. However, due to the staggered nature of the stage one firms' price increases, the firms at stage two do not immediately endure a full marginal cost increase. Thus, stage two firms that are able to renew contracts during the initial period will not choose to raise prices fully. At the end of the initial period, when all stage one firms have renewed their contracts, the marginal cost at stage two will also fully adjust and the stage two firms will now choose to fully increase prices when it is time to renew their contracts. Correspondingly, firms at higher stages will face even smaller changes in their marginal cost and have even less of an incentive to adjust prices. Thus, as production chain length increases, movements in the price level decrease and fluctuations in aggregate output become increasingly persistent.

The vertical input-output structure of the Huang and Liu (2001) model lends itself to the examination of economies at different levels of development. It is possible to represent countries at different levels of economic development simply by altering the number of stages of production involved. For example, the world's least economically developed countries, such as Malawi, rely very heavily on exports of agriculture and raw materials, whilst having very little industrial production. As such, these countries can be represented by a very simple input-output structure with just one or two stages of production. On the other hand, an emerging market economy, such as Malaysia, will have a much more developed multi-sector economy. Accordingly, more stages can be incorporated in the input-output structure to represent this.

Thus, given the premise of this chapter, which is to examine output persistence in developing countries, I propose to use the structure of the Huang and Liu (2001) model to generate persistent output fluctuations, in response to monetary policy shocks, in line with those observed for the developing countries.[2] Furthermore, I examine the relationship between output persistence and economic development.

The subsequent section examines the relationship between output persistence, as measured by its half-life, and economic development.[3] Section 5.3 describes the Huang and Liu (2001) model to be used in the analysis. Section 5.4 calibrates the model for a sample of developing countries and assigns the number of stages to be included in the input-output structures. Section 5.5 examines the sensitivity of the model to the key parameters. Section 5.6 presents the impulse response functions and associated half-lives for the calibrated countries, and discusses the success of the model in capturing the patterns of output persistence revealed in section 5.2. Finally, section 5.7 concludes.

## 5.2. OUTPUT PERSISTENCE

The central aim of this chapter is to model the persistence of output fluctuations in developing economies. However, it is first necessary to establish the nature of output persistence in these developing economies. Moreover, it is of particular interest to

[2] The analysis in Chapter 3 revealed that monetary shocks are important sources of business cycle fluctuation in developing economies. Furthermore, the observed procyclicality of the real wage and persistence of prices documented in Chapter 3, indicate the suitability of a New Keynesian model with nominal rigidity in the form of staggered price contracts.

[3] For the purposes of this chapter, level of economic development is measured by GDP per capita and Energy Use per capita.

establish whether there is any relationship between output persistence and economic development.

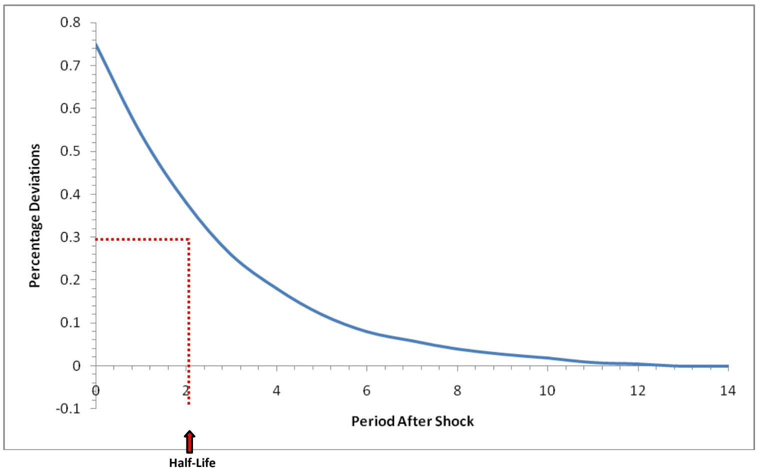
Chapter 3 reports autocorrelations of the cyclical components of either industrial or manufacturing production as a measure of output persistence. It provides evidence of significant output persistence in a wide spectrum of countries, but that the magnitude of output persistence is highest in the industrialised countries. However, as it is not easy to directly compare these results to the responses of output in the theoretical model, an alternative measure of persistence is required.

Assessment of the impact of the input-output structure on the persistence of output in the theoretical model is carried out by examining the half-life of the impulse response of output to a monetary shock. Thus, in order to compare the results of the theoretical model to the data, it is necessary to measure the persistence of output as its half-life.

### *5.2.1. Half-Life Measurement*

For the theoretical model, the half-life of output is defined as the length of time required for the response of output to a shock to halve. In this case, the half-life is clearly evident from observing the resultant impulse response function; see, for example, Figure 5.1.

**Figure 5.1 Measuring the Half-Life of an Impulse Response Function**




To calculate the half-life of output from the data, however, is not quite so straightforward. The procedure is simple and accurate where the data can be represented by a stationary AR(1) model. However, for models of higher orders {AR(p), p>1 and ARMA(p,q)} the correct procedure has faced much theoretical debate in the literature, especially amongst researchers interested in the puzzles associated with purchasing power parity (PPP).[4] For the purposes of this chapter, a standard approximation for the derivation of the half-life of a stationary AR(p) process is applied. The estimators for the AR(1) process and the AR(p) process are outlined below.

*The AR(1) model*

Define an AR(1) process:

$$y_t = \rho y_{t-1} + \varepsilon_t \tag{5.1}$$

where, $\varepsilon_t$ denotes a white noise innovation.

Then, the half-life is correctly estimated by

$$h = \frac{ln(1/2)}{ln(\hat{\rho})} \tag{5.2}$$

where, $\hat{\rho}$ is an estimate of $\rho$ .

*The AR(p) model*

Define an AR(p) process:

$$y_t = \sum_{j=1}^{\rho} \gamma_j y_{t-j} + \varepsilon_t \tag{5.3}$$

Take differences to obtain the error correction representation:

$$\Delta y_t = \gamma^* y_{t-1} + \sum_{j=1}^{\rho-1} \phi_j \Delta y_{t-j} + \varepsilon_t \tag{5.4}$$

where, $\phi_j = -\sum_{k=j+1}^{p} \gamma_k$ and $\gamma^* = \left( \sum_{i=1}^{p} \gamma_i \right) - 1$

Then for a stationary time series, the half-life can be approximated by:

$$h = \frac{ln(1/2)}{ln(1+\gamma^*)} \tag{5.5}$$

It is interesting to note that this reduces to the same formula as (5.2) for an AR(1) model.

[4] For a detailed discussion of the limitations of half-life measures, see: Chortareas and Kapetanios (2007); Seong *et al.*, (2006); and Choi *et al.*, (2006).

*5.2.2. Output Persistence*

Table 5.1 reports the half-life of output (in months) for the US, UK and Japan and 28 developing countries.[5]

As reliable quarterly real GDP data is not available for a large number of developing countries, indexes of industrial production are used as a proxy for the estimation of the half-life of output. The data is from the IMF International Financial Statistics (IMF) database; manufacturing production (IMF IFS series 66EY) and industrial production (IMF IFS series 66).

The data is deseasonalized using the Census Bureau's X12 ARIMA seasonal adjustment procedure and filtered using the Hoddrick Prescott Filter (λ=1600) to extract the stationary (cyclical) component. An ARMA(p,q) process, as selected by the maximisation of the Akaike information criterion, is then fitted to the cyclical components of output and the half-life calculated using method (5.5).

The Ljung-Box Q test, which tests for the serial correlation of the residuals, indicates that in most cases there is little evidence of serial correlation of the residuals in the selected model. The exceptions to this are the Côte d'Ivoire, Malawi, and Senegal; for these countries the half-life for the AR(1) model are reported as the higher order models {AR(2), AR(3), ARMA(1,1), ARMA(1,2), ARMA(2,1) and ARMA (2,2)} also displayed significant residual serial correlation.

It is clear from Table 5.1 that the persistence of output (as measured by its half-life) is greater in the industrialised countries than in the majority of the developing countries. However, there are a few exceptions. Given their GDP per capita rankings, both South Africa and the Philippines have remarkably large half-lives of output; however this is consistent with the turning point analysis in Chapter 2.

Conversely, given its GDP per capita ranking Brazil has a rather short output half-life. A possible explanation for the low persistence of output fluctuations in Brazil and the high degree of persistence experienced in the Philippines and South Africa relates to inflation. Whilst South Africa and the Philippines exhibit relatively low inflation rates,[6] Brazil experienced a period of hyperinflation during the late 1980s and early 1990s with an average annual inflation rate of 326% for the period 1991-2005. Thus, output appears to

[5] For more information about the countries included in this analysis see Chapter 2; in particular, see Table 2.2.
[6] The average annual inflation rate for the period 1980-2005 was below 10% in both the Philippines and South Africa.

be more persistent in low inflation economies, which is consistent with the findings of Kiley (2000). Finally, Hungary and Slovenia both display high output persistence. However, this is to be expected both from their relatively high GDP per capita rankings and from the earlier turning point analysis.[7] The average business cycle length for the Eastern European countries is very similar to that of the UK, US and Japan.

**Table 5.1** **Estimated Half-Lives of Output**

| Country | GDP per Capita Ranking (2003) | Sample Period | Model | Half-Life (in months) | Q value |
|---|---|---|---|---|---|
| US | 5 | 1980:1 – 2005:1 | AR(1) | 16.6 | 38.34 |
| UK | 20 | 1980:1 – 2005:1 | AR(1) | 9.9 | 55.44 |
| Japan | 21 | 1980:1 – 2005:1 | AR(2) | 11.1 | 38.94 |
| Argentina | 70 | 1994:1 – 2004:2 | ARMA(1,1) | 4.5 | 9.36 |
| Bangladesh | 176 | 1980:1 – 2004:4 | AR(2) | 2.2 | 37.56 |
| Brazil | 93 | 1991:1 – 2005:1 | AR(2) | 2.7 | 34.91 |
| Chile | 81 | 1980:1 – 2005:1 | AR(2) | 7.8 | 48.86 |
| Colombia | 110 | 1980:1 – 2005:1 | AR(1) | 3.7 | 44.84 |
| Côte d'Ivoire | 196 | 1980:1 – 2004:1 | AR(1) | 2.7 | 74.24** |
| Hungary | 62 | 1980:1 – 2005:1 | ARMA(1,2) | 9.8 | 26.55 |
| India | 152 | 1980:1 – 2004:4 | ARMA(1,1) | 4.4 | 53.01 |
| Israel | 44 | 1980:1 – 2004:4 | AR(2) | 6.3 | 45.07 |
| Jordan | 139 | 1980:1 – 2004:4 | AR(1) | 2.4 | 38.92 |
| Korea, South | 51 | 1980:1 – 2004:4 | AR(1) | 9.3 | 48.56 |
| Lithuania | 69 | 1993:1 – 2005:1 | AR(1) | 3.3 | 26.15 |
| Macedonia | 105 | 1993:1 – 2004:4 | AR(1) | 2.2 | 15.91 |
| Malawi | 230 | 1980:1 – 2004:2 | AR(1) | 2.1 | 59.09** |
| Malaysia | 84 | 1980:1 – 2004:4 | AR(2) | 7.5 | 54.04 |
| Morocco | 143 | 1980:1 – 2003:3 | AR(2) | 2.3 | 34.34 |
| Mexico | 86 | 1980:1 – 2005:1 | ARMA(1,2) | 5.8 | 51.21 |
| Nigeria | 211 | 1980:1 – 2003:4 | AR(1) | 3.7 | 47.10 |
| Pakistan | 170 | 1980:1 – 2004:3 | AR(1) | 1.1 | 22.97 |
| Peru | 122 | 1980:1 – 2005:1 | ARMA(1,2) | 4.6 | 46.14 |
| Philippines | 133 | 1980:1 – 2005:1 | AR(2) | 5.8 | 21.19 |
| Senegal | 192 | 1985:4 – 2003:4 | AR(1) | 2.2 | 62.42** |
| Slovak Republic | 65 | 1993:1 – 2005:1 | AR(1) | 4.9 | 24.98 |
| Slovenia | 49 | 1992:1 – 2005:1 | ARMA(1,2) | 10.6 | 34.08 |
| South Africa | 78 | 1980:1 – 2005:1 | AR(2) | 9.4 | 51.22 |
| Trinidad & Tobago | 75 | 1980:1 – 2003:4 | AR(2) | 2.8 | 39.05 |
| Turkey | 102 | 1980:1 – 2005:1 | AR(1) | 4.3 | 46.98 |
| Uruguay | 64 | 1980:1 – 2002:3 | AR(2) | 7.2 | 44.08 |

Significance is denoted by * if p<0.05 and ** if p<0.01

[7] See Chapter 2.

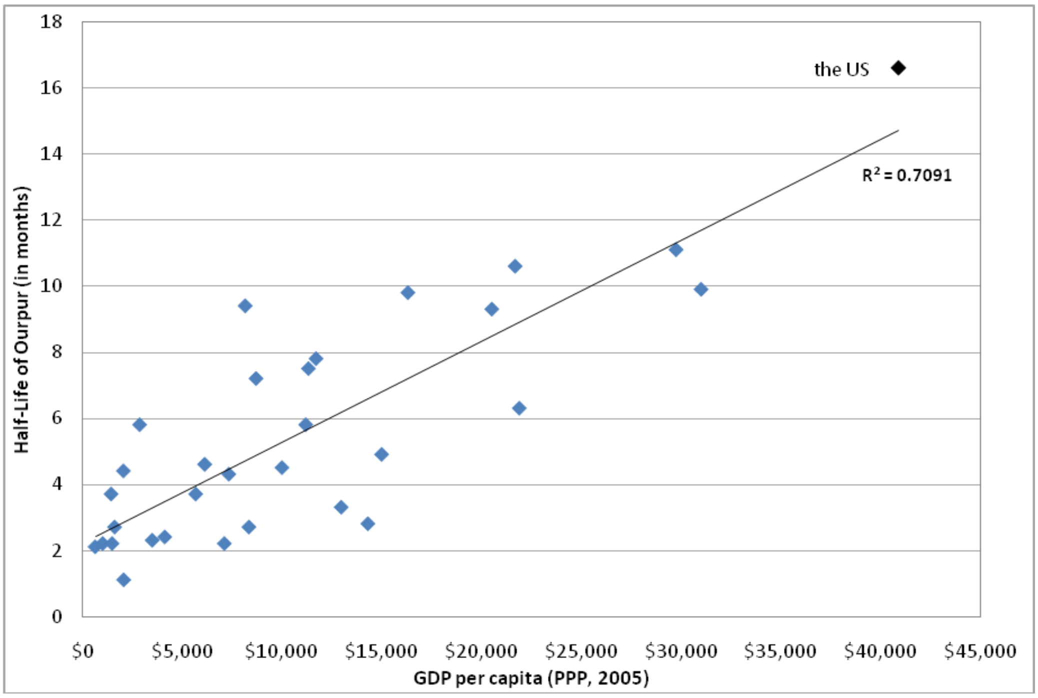
*5.2.3. Relationship between Economic Development and Output Persistence*

Economic development is measured both in terms of GDP per capita, and energy use per capita. Intuitively, energy use per capita is a good indicator of economic development. As economies develop, industrial production increases and urbanisation occurs, both of which significantly increase an economy's demand for energy. Consequently there is a close link between energy use per capita and economic growth, which is well documented in the literature (Yoo, 2006; Lee and Chang, 2007; and Zachariadis, 2007). Thus, it is employed here as an additional measure of economic development, in order to enhance the analysis.

The measure of GDP per capita is GDP per Capita, (PPP prices, constant 2005 international $) and Energy Use is Energy Use per Capita (kg of oil equivalent per capita, 2004); source World Bank World Development Indicators. Figure 5.2(a) plots the relationship between the half-life of output and GDP per capita, whilst Figure 5.3(a) plots the relationship between half-life and energy use per capita.

**Figure 5.2(a)**

**Relationship between Half-Life of Output and GDP per capita (PPP, 2005)**

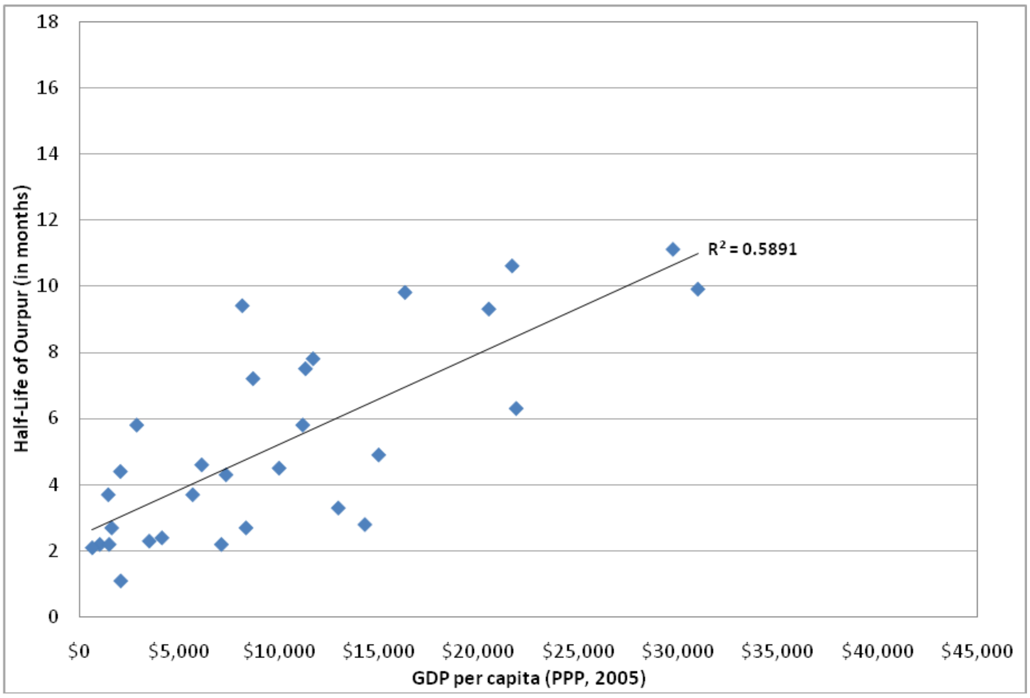



Note that each point of the graph represents an individual country's GDP per capita, for the year 2005, versus the country's estimated output half-life.

Examination of Figure 5.2(a) reveals that, as expected, there is a positive relationship between per capita GDP and output persistence. Consequently, this can be used to convey that there is a strong positive relationship between output persistence and economic development. However, it is evident that the US displays both much higher output persistence and significantly greater GDP per Capita than the other countries in this sample. Thus, Figure 5.2(b) plots the same relationship but with the exclusion of the US, to check whether this potential outlier does not significantly influence the results.

**Figure 5.2(b)**

**Relationship between Half-Life of Output and GDP per capita (PPP, 2005); excluding the US**



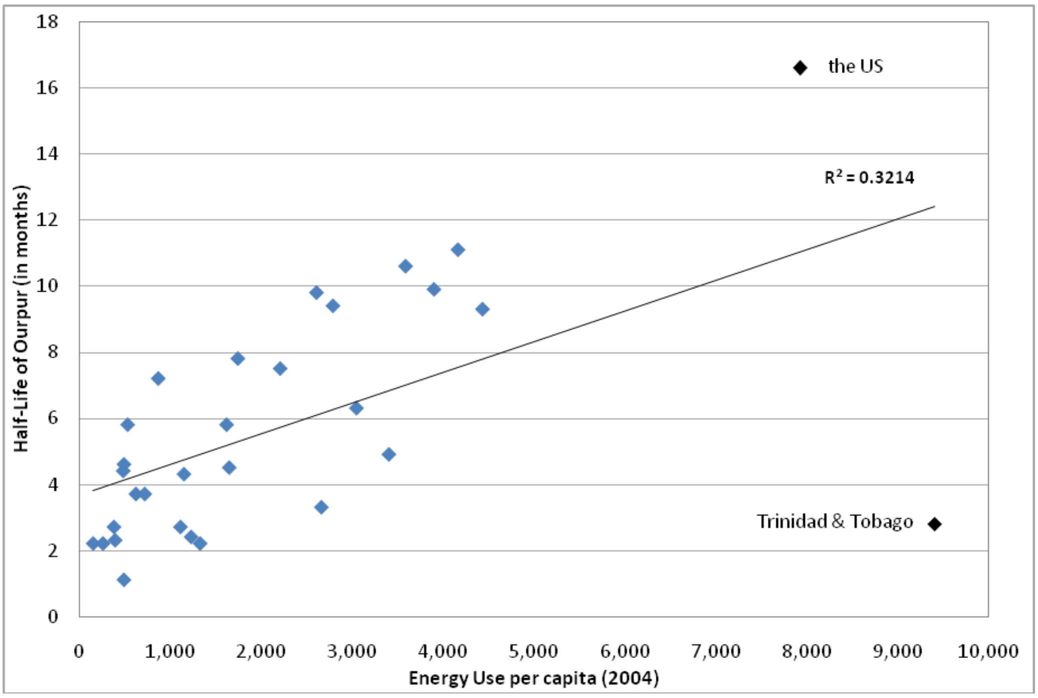

See Figure 5.2(a) for notes.

Whilst the exclusion of the US weakens the relationship slightly, with $R^2$ decreasing from 0.7091 to 0.5891, there is still evidence of a strong positive relationship between GDP per capita and output persistence. Thus, this preliminary analysis suggests that there is indeed a positive relationship between economic development and output persistence. For more detail, see the regression results provided in Table 5.2.

Subsequently, it necessary to see whether this relationship is also consistent with the alternative measure of economic development, energy use per capita. Figure 5.3(a) details the relationship between output persistence and energy use per capita. This figure shows that there is a positive relationship between per capita energy use and output persistence, as expected. This relationship is, however, somewhat weaker than the relationship between output per capita and output persistence. Further examination of the data points reveals two outliers in Trinidad and Tobago and the United States. Both countries have, what appear to be, excessive values for energy use per capita. However, the United States is a highly developed economy with an accordingly high half-life of output, and thus should be expected to have a high level of energy use. Conversely, whilst Trinidad and Tobago fall into the World Bank's upper middle income category, the country exhibits both relatively little output persistence (with a half-life of just 2.8 months) and excessively high energy consumption. The lack of output persistence in Trinidad and Tobago shall, for the moment, remain unexplained. However, a possible explanation for the surprisingly high per capita energy use in Trinidad and Tobago is the fact that the economy is largely based on petroleum and natural gas production and processing (this accounts for 40% of GDP) and there is evidence that oil-rich economies have higher energy consumption.[8]

**Figure 5.3(a)**

**Relationship between Half-Life of Output and Energy Use per capita (2004)**



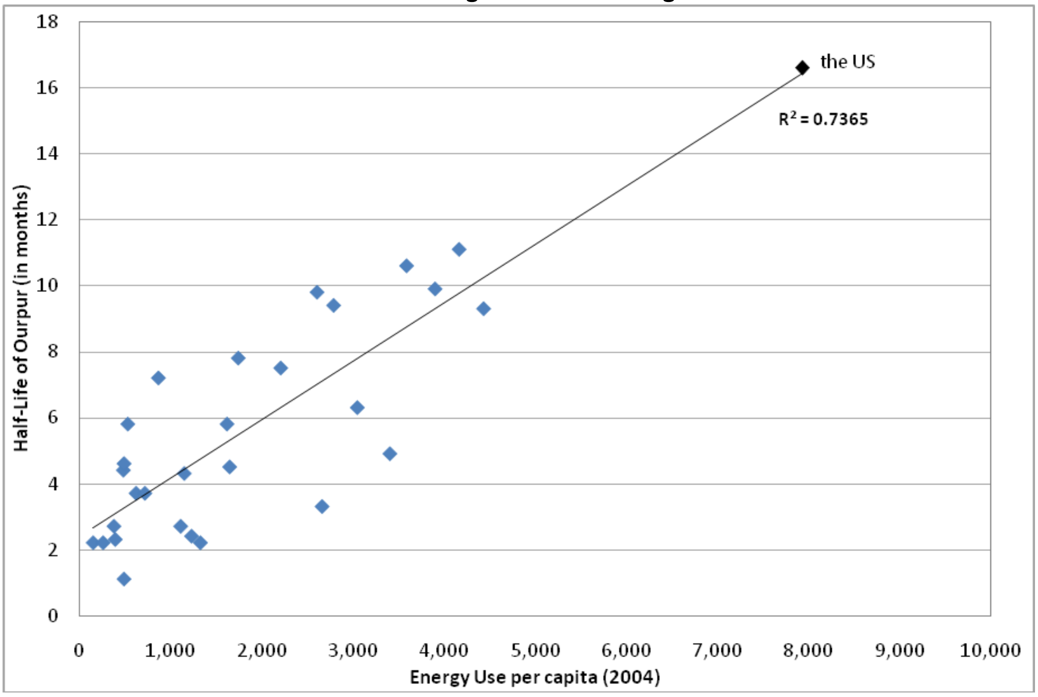

Note that each point on the graph represents an individual country's energy use per capita, for the year 2004, versus the country's estimated output half-life.

To examine the importance of these outliers in determining the relationship between energy use and output persistence, Figure 5.3(b) plots the relationship with the exclusion of Trinidad and Tobago, and Figure 5.3(c) plots the relationship with the exclusion of both the United States and Trinidad and Tobago.

[8] See the article Krauss, Clifford (2007) "Oil-Rich Nations Use More Energy, Cutting Exports" The New York Times; in print December 9, 2007.

**Figure 5.3(b)**

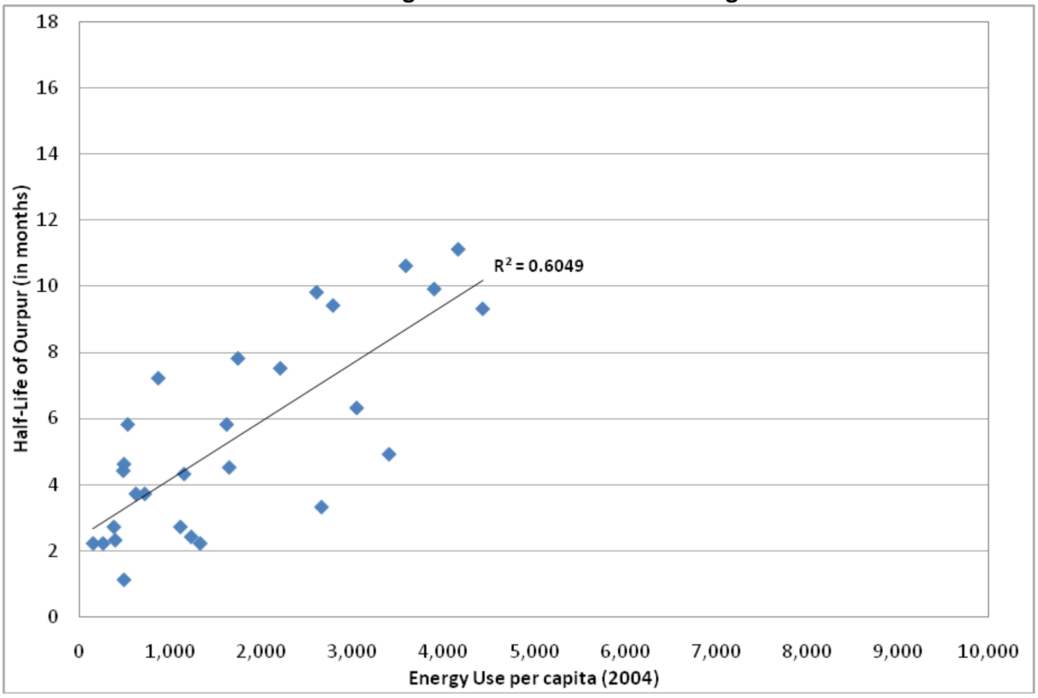
**Relationship between Half-Life of Output and Energy Use per capita (2004); excluding Trinidad & Tobago**




See Figure 5.3(a) for notes.

**Figure 5.3(c)**

**Relationship between Half-Life of Output and Energy Use per capita (2004); excluding the US and Trinidad & Tobago**




See Figure 5.3(a) for notes.

Excluding Trinidad and Tobago immediately reveals a much stronger positive relationship between energy use per capita and output persistence; see Figure 5.3b and the regression results in Table 5.2. However, the exclusion of the US once again weakens the relationship slightly. Despite this, there is still evidence of a strong positive relationship between energy use per capita and output persistence amongst the remaining twenty-nine countries.

To examine the relationship between output persistence and economic development in more detail, a simple linear regression between the half-life of output and GDP per capita (PPP, 2005) and energy use per capita (2004) is performed. To satisfy the necessary assumptions for the least squares regression, it was necessary to take logs of GDP per capta and Energy use per capita. The resulting regression equation is given by:

$$HL_i = \beta_0 + \beta_1 Ln\left(GDP_i\right) + \beta_2 Ln\left(ENERGY_i\right) + \varepsilon_i \qquad (5.6)$$

where, $HL_i$ is the half-life of output, $GDP_i$ is GDP per capita, $ENERGY_i$ is energy use per capita and $\varepsilon_i$~iid$(0,\sigma^2)$; i=1,..,n.

Table 5.2 details the simple linear regression results for the relationship between output persistence.[9,10]

**Table 5.2**

**Regression Results: Relationship between Output Persistence and Economic Development**

| | Model 1 | | | | Model 2 | | | | Model 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | A | B | C | D | A | B | C | D |
| Ln[GDP] | 2.396** | 2.008** | 2.494** | 2.112** | | | | | 2.681* | 2.477* | 1.278 | 1.341 |
| | (0.421) | (0.380) | (0.405) | (0.364) | | | | | (1.109) | (0.959) | (1.185) | (1.032) |
| Ln[Energy] | | | | | 2.261** | 1.806** | 2.797** | 2.341** | -0.111 | -0.362 | 1.568 | 1.046 |
| | | | | | (0.496) | (0.459) | (0.454) | (0.428) | (1.083) | (0.938) | (1.227) | (1.082) |
| Constant | -15.597** | -12.414** | -16.312** | -13.186** | -10.617** | -7.599* | -14.206** | -11.175** | -17.419** | -14.035** | -16.779** | -13.850** |
| | (3.749) | (3.359) | (3.600) | (3.212) | (3.618) | (3.319) | (3.278) | (3.057) | (4.367) | (3.914) | (4.047) | (3.652) |
| $R^2$ | 0.528 | 0.500 | 0.575 | 0.555 | 0.426 | 0.364 | 0.584 | 0.535 | 0.528 | 0.494 | 0.602 | 0.565 |
| F | 32.39** | 27.94** | 37.87** | 33.61** | 20.76** | 15.45** | 37.94** | 29.96** | 15.09** | 12.68** | 19.67** | 16.22** |

Significance is denoted by: * if p<0.05 and ** if p<0.01
Standard errors are reported in brackets.

A: All countries are included in the regression
B: The US is excluded from the regression
C: Trinidad & Tobago are excluded from the regression.
D: Both the US and Trinidad & Tobago are excluded from the regression.

The results for models one and two supports the graphical findings of a strong positive relationship between the half-life of output and economic development, as measured by GDP per capita (Model 1) and energy use per capita (Model 2). In models one and two,

[9] Diagnostic test results and residual plots are available in Appendix E.
[10] All statistical procedures in the chapter were performed using the statistical package STATA.

the coefficients on GDP per capita and energy use per capita, respectively, are all positive and significant. This indicates that each of these measures of economic development plays a statistically significant role in explaining the half-life of output. Thus, it can be said that output persistence is positively related to economic development; or that the more economically developed an economy the greater the persistence of output. Unfortunately, the joint effects of energy use per capita and GDP per capita on the half-life cannot be explored meaningfully due to the collinearity of GDP per Capita and energy use.[11]

This analysis has revealed that there is a strong positive relationship between economic development and output persistence. Thus, through the application of the Huang and Liu (2001) vertical production chain dynamic stochastic general equilibrium (DSGE) model, this chapter shall procede to attempt to model this relationship. The model is well suited to the task, as alteration of the number of production stages in the vertical chain will allow the representation of economies at different stages of economic development. A more economically developed economy, for example, will tend to have a more sophisticated input-output structure,[12] which can be modelled by increasing the number of production stages accordingly. Likewise, a very low income economy is likely to have a very simple input-output structure; thus, this could be modelled by introducing just two or three production stages. Furthermore, given the intuition behind the model, namely that: as the number of production stages increases, movements in the price level in responsee to a monetary shock decrease and thus output fluctuations become increasingly persistent. This should be able to reproduce the observed pattern of greater output persistence in more economically developed copuntries.

## 5.3. THE MODEL

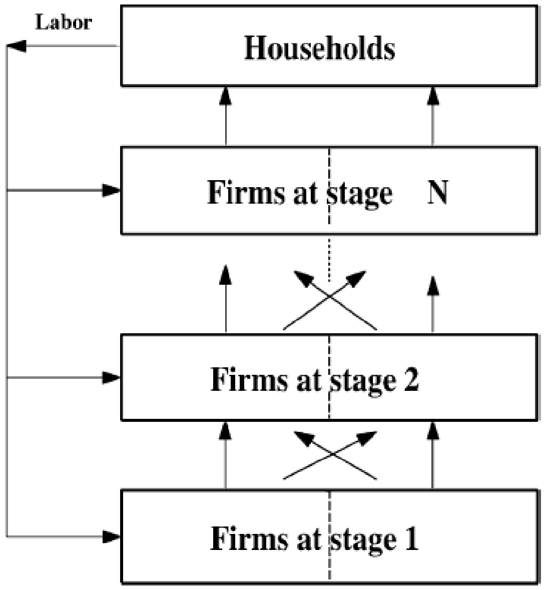
The model follows that of Huang and Liu (2001), which features a vertical input-output structure, as detailed in Figure 5.4, where the production of a final consumption good requires multiple stages of processing. At each stage, there is a continuum of monopolistically competitive firms, indexed $i \in [0,1]$, producing differentiated goods and setting prices in a staggered fashion. Firms at stage 1, require only labour input from a

[11] The relationship between GDP per capita and Energy Use per capita yields an $R^2$ value of 0.893 (when all countries are included in the regression).
[12] As documented by Leontief (1963).

representative household, whilst firms at stages $n \in [2,...,N]$ require labour input and goods produced at stage n-1.

In each period t, the economy experiences one of many events (monetary shocks) $s_t$. The history of events up to and including period t is given by $s^t = (s_{0,...,}s_t)$ and the probability of any particular history occurring is $\pi(s^t)$.

**Figure 5.4** **The Input-Output Structure of the Economy**




Huang and Liu (2001, p.442; Figure 1)

### *5.3.1. The Representative Household*

There is an infinitely lived representative household with preferences given by the discounted utility function:

$$\sum_{t=0}^{\infty}\sum_{s^t}\beta^t\pi(s^t)\left[\ln C(s^t)+\Phi\ln\left(\frac{M(s^t)}{\bar{P}_N(s^t)}\right)-\Psi L(s^t)\right] \tag{5.7}$$

Where, $\beta \in [0,1]$ is the subjective discount factor, $C(s^t)$ is consumption, $M(s^t)$ is nominal money balances, $L(s^t)$ is labour hours and $\bar{P}_N(s^t)$ is a price index for goods produced at the final stage.

The consumption good, $C(s^t)$, is a Dixit and Stigilitz (1977) composite of the final-stage goods:

$$C(s^t) = \left[ \int_0^1 Y_N\left(i, s^t\right)^{(\theta-1)/\theta} di \right]^{\theta/(\theta-1)} \equiv Y_N(s^t) \tag{5.8}$$

where, $Y_N\left(i, s^t\right)$ is a type i good produced at stage N and θ is the elasticity of substitution between these goods. $Y_N\left(s^t\right)$ can be interpreted as aggregate output corresponding to real GDP in the data.

Households choose their period t allocations of consumption, labour hours, nominal money balances and one-period bonds, $B\left(s^{t+1}\right)$, after the realisation of event $s_t$, in order to maximise their utility function (5.7) subject to a budget constraint (5.9) and a borrowing constraint (5.10):

$$\begin{aligned} &\int_0^1 P_N\left(i, s^t\right) Y_N\left(i, s^t\right) di + \sum_{s^{t+1}} D\left(s^{t+1} \middle| s^t\right) B\left(s^{t+1}\right) + M\left(s^t\right) \\ &\leq W\left(s^t\right) L\left(s^t\right) + \Pi\left(s^t\right) + B\left(s^t\right) + M\left(s^{t-1}\right) + T\left(s^t\right) \end{aligned} \tag{5.9}$$

where, $P_N\left(i, s^t\right)$ is the price of a type i consumption good, $W\left(s^t\right)$ is the nominal wage rate, $\Pi\left(s^t\right)$ are nominal profits distributed to the household and $T\left(s^t\right)$ are nominal lump-sum transfers from the monetary authority.

Each of the nominal bonds $B\left(s^{t+1}\right)$ is a claim to one dollar in the next period if event $s^{t+1}$ occurs. The bonds cost $D\left(s^{t+1} \middle| s^t\right)$ dollars at $s^t$. The household faces the following borrowing constraint:

$$B\left(s^t\right) \geq -\bar{B} \tag{5.10}$$

for some large positive $\bar{B}$.

Utility maximisation yields the demand for money:

$$\phi \frac{Y_N\left(s^t\right)}{m\left(s^t\right)} = \frac{r\left(s^t\right)}{1 + r\left(s^t\right)} \tag{5.11}$$

where, $m\left(s^t\right)$ is real money balances and $r\left(s^t\right)$ is the real interest rate.

And the demand for a type i good produced at stage N:

$$Y_N^d\left(i, s^t\right) = \left[ \frac{P_N\left(i, s^t\right)}{\bar{P}_N\left(s^t\right)} \right]^{-\theta} Y_N\left(s^t\right) \tag{5.12}$$

### *5.3.2. The Firms*

At each stage, there is a continuum of monopolistically competitive firms, indexed $i \in [0,1]$, producing differentiated goods. Firms at stage 1, simply require labour input from a representative household, whilst firms at stages $n \in [2,...,N]$ require labour input and a combination of goods produced at stage n-1. Firms are price-takers in their input-markets and price setters in their output markets. Assuming two-period staggered pricing, half of the firms at each stage can set new prices for their outputs in each period and this price remains effective for two periods.

Firm i at stage $n \in [1,...,N]$ that is able to set a new price at time t, will choose $P_n(i,s^t)$, after the realisation of $s^t$, to maximise:

$$Max \sum_{\tau=t}^{t+1} \sum_{s^t} D\left(s^\tau \middle| s^t\right)\left[P_n\left(i,s^t\right) - V_n\left(i,s^\tau\right)\right] Y_n^D\left(i,s^\tau\right) \qquad (5.13)$$

Taking unit cost $V_n(i,s^\tau)$ and the demand schedule $Y_n^D(i,s^\tau)$ as given.

*(a) Production at Stage 1*

Production by firms at stage 1 requires only labour input, $L_1(i,s^t)$, from a representative household. Production has constant returns to scale, and is described by the following function:

$$Y_1\left(i,s^t\right) = L_1\left(i,s^t\right) \qquad (5.14)$$

where, $Y_1(i,s^t)$ is the output of a stage 1 firm of type i.

Since firms at stage 1 only employ labour as an input, the unit cost is simply the nominal wage rate:

$$V_1\left(s^t\right) \equiv V_1\left(i,s^t\right) = W\left(s^t\right) \qquad (5.15)$$

*(b) Production at Stage n;* $n \in [2,...,N]$

Production by firms at stage n, $n \in [2,...,N]$, requires labour input from the representative household and a composite of the goods produced at stage n-1, with production function:

$$Y_n\left(i,s^t\right)=\left[\int_0^1 Y_{n-1}\left(i,j,s^t\right)^{(\theta-1)/\theta}dj\right]^{\theta\gamma/(\theta-1)}L_n\left(i,s^t\right)^{1-\gamma} \qquad (5.16)$$

where, $Y_n\left(i,s^t\right)$ is the output of a stage n firm of type i, $Y_{n-1}\left(i,j,s^t\right)$ is the output of a stage n-1 firm of type j supplied as an input to i, $L_n\left(i,s^t\right)$ is labour input and $\gamma\in[0,1]$ is the share of stage n-1 goods in i's production.

In this case, cost minimisation yields the following unit cost:

$$V_n\left(s^t\right)\equiv V_n\left(i,s^t\right)=\tilde{\gamma}\bar{P}_{n-1}\left(s^t\right)^{\gamma}W\left(s^t\right)^{1-\gamma} \qquad (5.17)$$

where, $\tilde{\gamma}=\gamma^{-\gamma}(1-\gamma)^{\gamma-1}$ and $\bar{P}_{n-1}\left(s^t\right)\equiv\left[\int_0^1 P_{n-1}\left(j,s^t\right)^{1-\theta}dj\right]^{1/(1-\theta)}$ is a price index of goods produced at stage n-1. Assuming constant returns to scale in the production function, unit cost equals marginal cost and is firm independent.

Firms at stage $n\in[2,...,N]$ demand inputs of labour and goods produced at stage n-1. Solving the cost minimisation problem for firms at stage n+1 yields the input demand function for the intermediate goods $\left(n\in[1,...,N-1]\right)$:

$$Y_n^d\left(i,s^t\right)=\left[\frac{\gamma}{1-\gamma}\right]^{1-\gamma}\left[\frac{P_n\left(i,s^t\right)}{\bar{P}_n\left(s^t\right)}\right]^{-\theta}\left[\frac{\bar{P}_n\left(s^t\right)}{W\left(s^t\right)}\right]^{\gamma-1}\tilde{Y}_{n+1}\left(s^t\right) \qquad (5.18)$$

Finally, need to solve for the optimal pricing decision rule for firms at all stages, $n\in[1,...,N]$. Taking unit cost and the demand schedule as given, solving the profit maximisation problem (5.13) provides:

$$P_n\left(i,s^t\right)=\frac{\theta}{(\theta-1)}\frac{\sum_{\tau=t}^{t+1}\sum_{s^\tau}D\left(s^\tau\middle|s^t\right)Y_n^d\left(i,s^\tau\right)V_n\left(s^\tau\right)}{\sum_{\tau=t}^{t+1}\sum_{s^\tau}D\left(s^\tau\middle|s^t\right)Y_n^d\left(i,s^\tau\right)} \qquad (5.19)$$

This implies optimal price is simply a constant mark-up over marginal costs.

*5.3.3. The Monetary Authority*

The nominal money supply process is given by:

$$M^S\left(s^t\right)=\mu\left(s^t\right)M^S\left(s^{t-1}\right) \tag{5.20}$$

where, $\mu\left(s^t\right)$ is a stochastic process.

The new money balances are distributed to the economy via lump-sum nominal transfers to the household:

$$T\left(s^t\right)=M^S\left(s^t\right)-M^S\left(s^{t-1}\right) \tag{5.21}$$

### *5.3.4. Equilibrium*

An equilibrium for this economy, consists of allocations for the households and firms at all stages $\left(n\in[1,...,N]\right)$ together with a wage rate $W\left(s^t\right)$, bond prices $D\left(s^{t+1}\middle|s^t\right)$ and price indices $\left\{\bar{P}_n\left(s^t\right)\right\}_{n\in[1,...,N]}$ that satisfy:

i. taking prices and wages as given, the household's allocations solve the utility maximisation problem (5.7)
ii. taking all prices but its own and wages as constant, each firm's price solves its profit maximisation problem (5.13)
iii. markets for labour, money and bonds clear

### *5.3.5. Model Solution*

*(a) Log-Linearized Model*

Following Huang and Liu (2001), the analysis focuses on a symmetric equilibrium where firms in the same cohort make identical pricing decisions. As such, firms can be identified simply by the stage at which they produce and the time at which they are able to change prices. Accordingly, $P_n\left(t\right)$ denotes prices set at time t for goods produced at stage $n\in\left[1,...,N\right]$ and the identifying i and j indices are dropped.

The equilibrium conditions are reduced to a system of 2N + 2 equations: N pricing equations, N price level equations, a labour supply equation and a money demand equation. These simplified equilibrium conditions are log-linearized around a steady-state yielding the following log-linearized equations:

i. The linearized pricing rule for firms at stage $n \in [1, ..., N]$

$$0 = \frac{1}{1+\beta}\left[\gamma \overline{p}_{n-1}(t) + (1-\gamma) w(t)\right] - p_N(t) + \frac{\beta}{1+\beta} \mathrm{E}_t \left[\gamma \overline{p}_{n-1}(t+1) + (1-\gamma) w(t+1)\right] \quad (5.22)$$

ii. The price index for goods produced at stage $n \in [1, ..., N]$

$$\overline{p}_n(t) = \frac{1}{2}\left[p_n(t-1) + p_n(t)\right] \quad (5.23)$$

iii. The labour supply decision of the household

$$0 = y_N(t) + \overline{p}_N(t) - w(t) \quad (5.24)$$

iv. The money demand equation

$$0 = (1-\beta) m(t) - y_N(t) - \overline{p}_N(t) + \beta \mathrm{E}_t \left[\overline{p}_N(t+1) + y_N(t+1)\right] \quad (5.25)$$

v. The money supply equation

$$m(t) = m(t-1) + \varepsilon(t) \quad (5.26)$$

Lowercase letters are used to indicate log-deviations of the corresponding variable from its steady-state in the log-linearized equations.

*(b) Numerical Solution of Log-Linearized System*

The model is solved numerically through the application of the Uhlig (1997) toolkit, which uses the method of undetermined coefficients to solve for the recursive equilibrium law of motion. This requires the calibration of the model parameters, and the log-linearization of the necessary equilibrium conditions around the steady-state, as above. The complete log-linearized model must then be summarised in the following system of equations:

$$0 = AAx(\mathrm{t}) + BBx(\mathrm{t\text{-}1}) + CCy(\mathrm{t}) + DDz(\mathrm{t}) \quad (5.27)$$

$$0 = \mathrm{E}_t\left[FFx(\mathrm{t+1}) + GGx(\mathrm{t}) + HHx(\mathrm{t\text{-}1}) + JJy(\mathrm{t+1}) KKy(\mathrm{t}) + LLz(\mathrm{t+1}) + MMz(\mathrm{t})\right] \quad (5.28)$$

$$z(\mathrm{t+1}) = NNz(\mathrm{t}) + \varepsilon(\mathrm{t+1}) \quad (5.29)$$

where, x(t) = [$y_1$(t),…, $y_N$(t), $p_1$(t),…, $p_N$(t)] are the endogenous state variables, y(t) = [$v_1$(t),…, $v_N$(t), $l_1$(t),…, $l_N$(t), w(t)] are the endogenous other variables and z(t) = [m(t)] is the exogenous state variable.

The Uhlig (1997) toolkit then solves for the equilibrium law of motion:

$$x(t) = PPx(t-1) + QQz(t) \tag{5.30}$$

$$y(t) = RRx(t-1) + SSz(t) \tag{5.31}$$

Details of the first-order conditions, steady-states, and log-linearizations necessary for the solution of this model, as well as definitions of the required matrices, are provided in Appendix D.

## *5.4. CALIBRATION*

### *5.4.1. Parameter Calibration*

The parameters for calibration are the subjective discount factor β, the monetary policy parameters $\rho_\mu$ and $\sigma_\mu$, the goods demand elasticity parameter θ, the share of the composite of stage (n-1) goods in i's production γ, and finally the preference parameters Φ and Ψ, which determine the relative weight of real money balances and leisure time, respectively, in the utility function.

The sources of data for the calibrations are the IMF International Financial Statistics (IFS), the OECD Input-Output Tables and the International Labour Organization (ILO) Bureau of Statistics LABORSTA.

Limitations in the availability of the data necessary to complete the calibrations, dictates that the sample of developing countries has to be cut to seventeen countries, out the original thirty-two country sample. The developing countries for which the necessary data are available are: Argentina, Brazil, Colombia, Chile, Hungary, India, Israel, Lithuania, Malaysia, Mexico, Peru, the Philippines, the Slovak Republic, Slovenia, South Africa, South Korea, and Turkey. The calibrations for these countries are summarised in Table 5.3, along with the calibrated parameters for the US, UK and Japan.

*The Subjective Discount Factor*

Using data for the quarterly money market rate (IMF IFS series 60B), the subjective discount factor (β) is calculated from the steady-state Euler equation:

$$1 = \beta(1 + r^*) \tag{5.32}$$

where, r* is the real interest rate.

For the US, the average real interest rate for the period 1965:3 – 2003:4 is 0.18, yielding a subjective discount factor of 0.85. Similarly, for India (1965:3 – 2003:1) the average real interest rate is 0.39 yielding $\beta = 0.72$ and for Brazil (1994:3 – 2005:2) the average real interest rate is 0.65 yielding a very low $\beta$ of 0.61.

*The Monetary Policy Parameters*

These are calculated from a simple AR(1) process on quarterly M1 data (IMF IFS series 34):

$$\log(\mu_t) = \rho \log(\mu_{t-1}) + \varepsilon_t \tag{5.33}$$

where $\rho_\mu$ is the AR(1) coefficient in the money growth process and $\sigma_\mu$ is the standard deviation of $\varepsilon_t$.

For the US, the calculated values of $\rho_\mu$ and $\sigma_\mu$ are 0.47 and 0.101 respectively for M1 growth over the period 1965:3 – 2003:4. Similarly, for India (1965:3 – 2003:1) $\rho_\mu$ is 0.04 and $\sigma_\mu$ is 0.04 and for Brazil (1994:3 – 2005:2) $\rho_\mu$ is 0.92 and $\sigma_\mu$ is 0.03.

*The Goods Demand Elasticity Parameter*

The goods demand elasticity parameter $\theta$ determines the steady-state mark-up of price over marginal cost.

Following Huang and Liu (1999), $\theta_n$ is set equal to $\theta$ and a value of $\theta$ is assigned such that the model implies a constant steady-state price cost margin (PCM) for each country. For the model, the PCM is defined as:

$$PCM = \frac{\bar{P}_N - \nu \bar{P}_N}{\bar{P}_N} = 1 - \nu \tag{5.34}$$

where, $\nu = \left((\theta - 1)/\theta\right)^N$ is steady-state unit cost. This relationship is used to determine the value of $\theta$.

The value of the PCM is calculated using data from the OECD Input-Output Tables (2005), using the following definition:

$$PCM = \frac{\text{value added} - \text{compensation of employees}}{\text{industry output}} \tag{5.35}$$

For consistency, since output is measured by either manufacturing production (IMF IFS series 66EY) or industrial production (IMF IFS series 66), all of the values calculated from the OECD Input-Output tables are calculated solely from industries contained in Major Division 3 (Manufacturing) of the International Standard Industrial Classification of all Economic Activities (ISIC-Rev.2, 1968).

From the 2000 OECD input-output table for the US (currency = million US $), value added is 70134.14, compensation is 45315.77 and industry output is 199395.17; all of the preceding values are averages over all the manufacturing industries. This yields a price-cost margin of 0.13, giving a steady-state unit cost of 0.87, from which theta is calculated to be 27.5. Similarly, for India (1998 input-output table; currency = Rupees in Lakhs), value added is 1139937.62, compensation is 0 and industry output is 4503581.14 yielding a price cost margin of 0.27. Hence, steady-state unit cost for India is 0.74 and theta is 13.5. Finally for Brazil (2000 input-output table; currency = thousand Real), value added is 12347513.92, compensation is 3130746.48 and industry output is 35864106.36, yielding a price cost margin of 0.25. Hence, steady-state unit cost for Brazil is 0.75 and theta is 14.6.

*The Share of Composite of Stage (n-1) Goods in i's Production,* $\gamma \in (0,1)$

From the steady-state relationships,

$$\frac{1}{1-\eta} = \sum_{n-1}^{N} \frac{\bar{P}_n Y_n}{\bar{P}_N \bar{Y}_N} = \frac{1-(\gamma/\mu)^N}{1-(\gamma/\mu)} \tag{5.36}$$

where, N is the number of processing stages, γ is the share of composite of stage (n-1) goods in i's production, η is the share of intermediate goods in total manufacturing and $\mu = \theta/(\theta-1)$ is the steady-state mark-up of price over marginal cost.

The value of the steady-state mark-up of price over marginal cost is determined by the value of θ.

The value of η is calculated using the OECD Input-Output Tables (2005) and is defined as:

$$\eta = \frac{\text{industry output } - \text{ value added}}{\text{industry output}} \tag{5.37}$$

For the US, the share of intermediate goods in total manufacturing is 0.637, as calculated from the 2000 OECD input-output table. The steady-state mark-up of price over marginal cost is 1.035, given $\theta$ = 29.5. These yield $\gamma$ = 0.787. Similarly for India, the share of intermediate goods in total manufacturing is 0.735, the steady-state mark-up of price over marginal cost is 1.082 (given $\theta$ = 14.6), yielding $\gamma$ = 0.92. Finally for Brazil, the share of intermediate goods in total manufacturing is 0.648, the steady-state mark-up of price over marginal cost is 1.074 (given $\theta$ = 14.6), yielding $\gamma$ = 0.831.

*The Relative Weight of Real Money Balances*

This is calculated using the implied steady-state money demand equation:

$$\Phi = \frac{M^*}{\bar{P}_N * C^*}\left(\frac{R^* - 1}{R^*}\right) \tag{5.38}$$

where, R* is the steady-state nominal interest rate and $\bar{P}_N * C^* / M^*$ is the steady-state consumption velocity.

Consumption velocity is the ratio of consumption expenditures to real money balances and is calculated here using M1 (IMF IFS series 34), Private Consumption (IMF IFS series 96F) and CPI (IMF IFS series 64).

For the US (1965:3 – 2003:4), average consumption velocity is 0.07 and average nominal money market rate is 1.73, giving a real money balances parameter ($\Phi$) of 0.029. Similarly for India (1965:3 – 2003:1), average consumption velocity is 0.07 and average nominal money market rate is 2.025, giving a real money balances parameter ($\Phi$) of 0.033 and for Brazil (1994:3 – 2005:2), average consumption velocity is 0.14 and average nominal money market rate is 4.175, giving a real money balances parameter ($\Phi$) of 0.109.

*The Relative Weight of Leisure Time*

This is derived from annual data for the hours of work in manufacturing (per week) (ILO LABORSTA series 4B). For the US, the average time devoted to market activity for the period 1970 to 2005 is 40.7 hours per week or ¼; for the model to predict an average share of time allocated to market activity of ¼ then requires $\Psi$ equal to 1.13. Similarly for India, the average time devoted to market activity for the period 1982 to 2004 is 46.4

hours per week or $^2/_7$ requiring Ψ equal to 1.29. Finally, the average time devoted to market activity in Brazil (2000 to 2004) is 43.8 hours per week or ¼ which requires Ψ to equal to 1.22. It is interesting to note that most business cycle models assume the average share of time devoted to market activity is $^1/_3$ which then implies a Ψ of 1.56; thus, overestimating the relative weight of leisure time.

The calibrated parameters for each country are summarised in Table 5.3.

**Table 5.3** **Calibrated Parameters**

| Country | β | $\rho_\mu$ | $\sigma_\mu$ | Φ | Ψ | θ | γ |
|---|---|---|---|---|---|---|---|
| Argentina | 0.87 | 0.69 | 0.06 | 0.030[a] | 1.24 | 9.24 | 0.84 |
| Brazil | 0.61 | 0.92 | 0.03 | 0.109 | 1.22 | 17.52 | 0.83 |
| Colombia | 0.71 | 0.57 | 0.07 | 0.004 | 1.20 | 13.38[a] | 0.83[a] |
| Chile | 0.74 | 0.66[a] | 0.05[a] | 0.002 | 1.25[a] | 13.38[a] | 0.83[a] |
| Mexico | 0.72 | 0.81 | 0.03 | 0.003 | 1.26 | 13.38[a] | 0.83[a] |
| Peru | 0.78 | 0.31 | 0.05 | 0.030[a] | 1.31 | 13.38[a] | 0.83[a] |
| **Average** | **0.74** | **0.66** | **0.05** | **0.030** | **1.25** | **13.38** | **0.83** |
| India | 0.72 | 0.04 | 0.04 | 0.150[a] | 1.29 | 10.45 | 0.90 |
| Korea, South | 0.86 | 0.25 | 0.07 | 0.012 | 1.40 | 19.75 | 0.89 |
| Malaysia | 0.89 | 0.58 | 0.06 | 0.008 | 1.35[a] | 14.03[a] | 0.84[a] |
| Philippines | 0.79 | 0.42 | 0.05 | 0.010 | 1.36 | 14.03[a] | 0.84[a] |
| Turkey | 0.82[a] | 0.32[a] | 0.06[a] | 0.557 | 1.33 | 11.90 | 0.73 |
| **Average** | **0.82** | **0.32** | **0.06** | **0.150** | **1.35** | **14.03** | **0.84** |
| Hungary | 0.76 | 0.74 | 0.08 | 0.010[a] | 1.08[a] | 35.00 | 0.90 |
| Lithuania | 0.86 | 0.66 | 0.11 | 0.005 | 1.08 | 32.63[a] | 0.83 |
| Slovenia | 0.80 | 0.68 | 0.06 | 0.004 | 1.08 | 32.63[a] | 0.91 |
| Slovak Republic | 0.85 | 0.08 | 0.21 | 0.009 | 1.08[a] | 30.25 | 0.95 |
| **Average** | **0.82** | **0.54** | **0.12** | **0.010** | **1.08** | **32.63** | **0.93** |
| Israel | 0.79 | 0.13 | 0.04 | 0.023 | 1.12 | 50.00 | 0.89 |
| South Africa | 0.67 | 0.58 | 0.07 | 0.015 | 1.23 | 28.60 | 0.87 |
| **Average** | **0.73** | **0.35** | **0.05** | **0.019** | **1.17** | **39.30** | **0.88** |
| Japan | 0.91 | 0.53 | 0.05 | -0.169 | 1.14[a] | 34.50 | 0.93 |
| UK | 0.79 | 0.50[a] | 0.08[a] | -0.070[a] | 1.15 | 47.00 | 0.79 |
| US | 0.85 | 0.47 | 0.10 | 0.029 | 1.13 | 29.50 | 0.78 |
| **Average** | **0.85** | **0.50** | **0.08** | **-0.070** | **1.14** | **37.00** | **0.84** |

[a] Indicates that the regional average is used.

### *5.4.2. Number of Stages (N)*

The relationship between economic development and the sophistication of an economy's input-output structure is well documented in the literature. In particular, the seminal work of Leontief (1963) demonstrated that the larger and more developed an economy, the more complete is its economic structure. Consequently, it is assumed that the more developed an economy, as measured here as measured by real GDP per capita and energy use per capita, the more sophisticated the input-out structure and thus the greater the number of production stages. It has not been possible to estimate the complexity of each economy's input-output structure and consequently calibrate the number of stages. Therefore, instead, the sophistication of the input-output structure is estimated by the country's relative level of economic development. Consequently, countries are ranked according to a weighted average of real GDP per capita and energy use per capita (2004 values) and grouped with countries of similar weighted averages. Each of these groups is then assigned an N value corresponding to the development ranking. The rankings and N values are shown in Table 5.4.

**Table 5.4** **Number of Stages (N)**

| Country | GDP Rank (2003) | Energy Use & GDP | Half Life (in months) | Group | N |
|---|---|---|---|---|---|
| Bangladesh | 176 | 6.0 | 2.2 | 1 | 2 |
| Senegal | 192 | 6.4 | 2.2 | 1 | 2 |
| Côte d'Ivoire | 196 | 6.7 | 2.7 | 2 | 3 |
| India | 152 | 6.9 | 4.4 | 2 | 3 |
| Pakistan | 170 | 6.9 | 1.1 | 2 | 3 |
| Nigeria | 211 | 6.9 | 3.7 | 2 | 3 |
| Morocco | 143 | 7.1 | 2.3 | 3 | 5 |
| Philippines | 133 | 7.1 | 5.8 | 3 | 5 |
| Peru | 122 | 7.5 | 7.4 | 3 | 5 |
| Colombia | 110 | 7.5 | 3.7 | 3 | 5 |
| Jordan | 139 | 7.7 | 2.4 | 4 | 8 |
| Uruguay | 64 | 7.9 | 7.2 | 4 | 8 |
| Turkey | 102 | 8.0 | 4.3 | 4 | 8 |
| Brazil | 93 | 8.0 | 2.7 | 4 | 8 |
| Macedonia | 105 | 8.0 | 2.2 | 4 | 8 |
| Argentina | 70 | 8.3 | 4.5 | 5 | 13 |
| Mexico | 86 | 8.4 | 5.8 | 5 | 13 |
| Chile | 81 | 8.4 | 7.8 | 5 | 13 |
| South Africa | 78 | 8.5 | 9.4 | 5 | 13 |
| Malaysia | 84 | 8.5 | 7.5 | 5 | 13 |
| Lithuania | 69 | 8.7 | 3.3 | 6 | 21 |
| Hungary | 62 | 8.8 | 9.8 | 6 | 21 |
| Slovak Republic | 65 | 8.9 | 4.9 | 6 | 21 |
| Israel | 44 | 9.0 | 6.3 | 6 | 21 |
| Slovenia | 49 | 9.1 | 10.6 | 7 | 34 |
| Korea, South | 51 | 9.2 | 9.3 | 7 | 34 |
| UK | 20 | 9.3 | 9.9 | 7 | 34 |
| Japan | 21 | 9.3 | 11.1 | 7 | 34 |
| US | 5 | 9.8 | 16.6 | 8 | 55 |

As the model demonstrates diminishing returns, in terms of output persistence, for each additional production stage, the N values are assigned according to a Fibonacci sequence (1,1,2,3,5,8,13,21,34,55,…). The least developed countries (namely Bangladesh and Senegal) are assigned a value of N = 2, whilst the most developed country (namely the US) is assigned a value of N = 55.

## 5.5. SENSITIVITY ANALYSIS

The central premise of the model is that through the input-output relations across stages and the staggered prices within stages, it is possible to generate persistent output fluctuations in response to monetary policy shocks. In theory, as the number of stages increase, movements in the price level should decrease, and fluctuations in aggregate output should become increasingly persistent. Thus, this section examines the importance of the number of stages, N, in generating output persistence and the sensitivity of the results to the calibrated parameter values.

From the system of log-linearized equations, equations (5.21) to (5.25), it is evident that the key parameters in determining the extent of output persistence are the share of the composite of stage (n-1) goods in i's production (γ) and the subjective discount factor (β). The effect of changing these parameters is examined for three representative countries, Brazil, India and the US.

The magnitude of persistence is measured using both the half-life of output, as defined in section 5.2.1, and the contract multiplier. The contract multiplier, as proposed by Chari *et al.* (2000), measures the degree to which the real effect of the monetary policy shock extends beyond the initial contract duration; the higher the ratio, the more persistent the response of output to the monetary shock. With two cohorts of price setters, as in this model, the contract multiplier is defined as the ratio of the output response after 6 months to that at time zero.

In what follows, with the exception of the parameter of interest, all the parameters are as calibrated for the particular country.

### *5.5.1. The subjective discount factor (β)*

This compares the output persistence generated by the model, in response to a one-percent monetary shock, when β is at its minimum calibrated value (0.61 Brazil), when β is at its maximum calibrated value (0.91 Japan), when β takes on the extreme values of 0.5 and 0.99, and when β is at its actual calibrated value for the country. The impulse response functions are presented in Figure 5.5 and the peak responses, contract multipliers and half-lives are reported in Table 5.5.

From Figure 5.5 it is possible to see that the smaller the value of β, the greater the degree of output persistence generated by the model. This effect is limited, although it does appear to be magnified slightly when the number of stages of production (N) is larger. For example, the impulse response functions are slightly more spread out for the US and Brazil than for India.

Looking at Table 5.5, it is obvious that the impact of a change in β for a change in the half-life is limited. All three countries show less than a one month increase in the half-life when β decreases from it maximum calibrated value of 0.91 to its minimum calibrated value of 0.61.

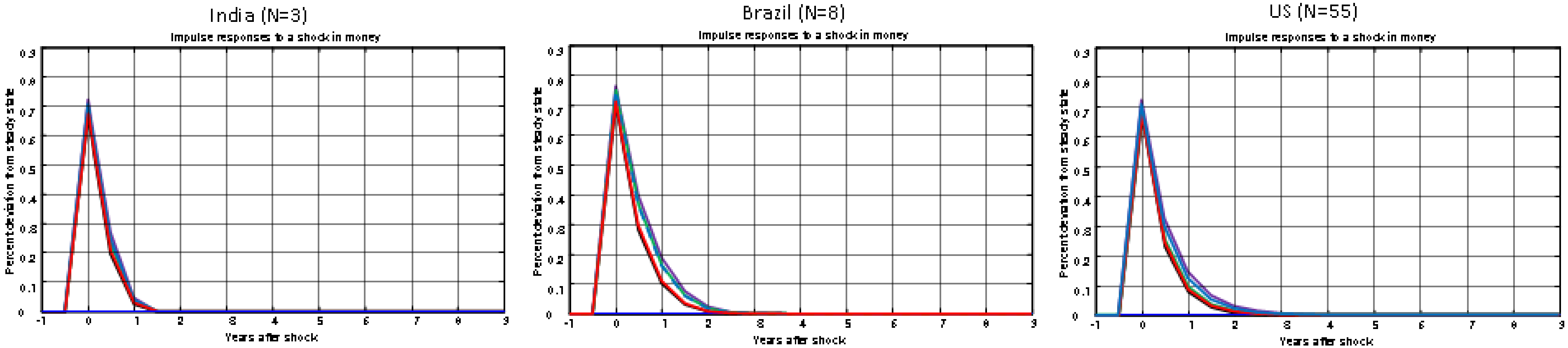
### *5.5.2. The share of the composite of stage (n-1) goods in i's production (γ)*

This compares the output persistence generated by the model when γ is at its minimum calibrated value (0.73 Turkey), when γ is at its maximum calibrated value (0.95 Slovak Republic), when γ takes on the extreme values of 0.5 and 0.99, and when γ is at its actual calibrated value for the country. The impulse response functions are presented in Figure 5.6 and the peak responses, contract multipliers and half-lives are reported in Table 5.6.

From Figure 5.6, it is clear that the larger the value of γ, the greater is the degree of output persistence generated by the model and that this effect is magnified as the number of stages (N) increases. The spread between the impulse response functions is clearly greater for the US, with N=55, than for either India (N=3) or Brazil (N=8).

Looking at Table 5.6 the importance of the value of γ on output, and the magnification effect, is clearly demonstrated in the values of the half-lives and the contract multipliers. For the US, the difference is substantial; with the lowest value of γ (0.5) the model generates a half-life of just 1.2 quarters whilst when γ takes on the largest value of 0.99 the half-life increases to almost 2 years (21.9 months). In the previous analysis, the half-life of output for the US was 16.6 months, thus the model is clearly capable of generating enough persistence to match the data so long as the value of γ for the economy is large enough.

**Figure 5.5** **Sensitivity of the Impulse Response of Output to β**

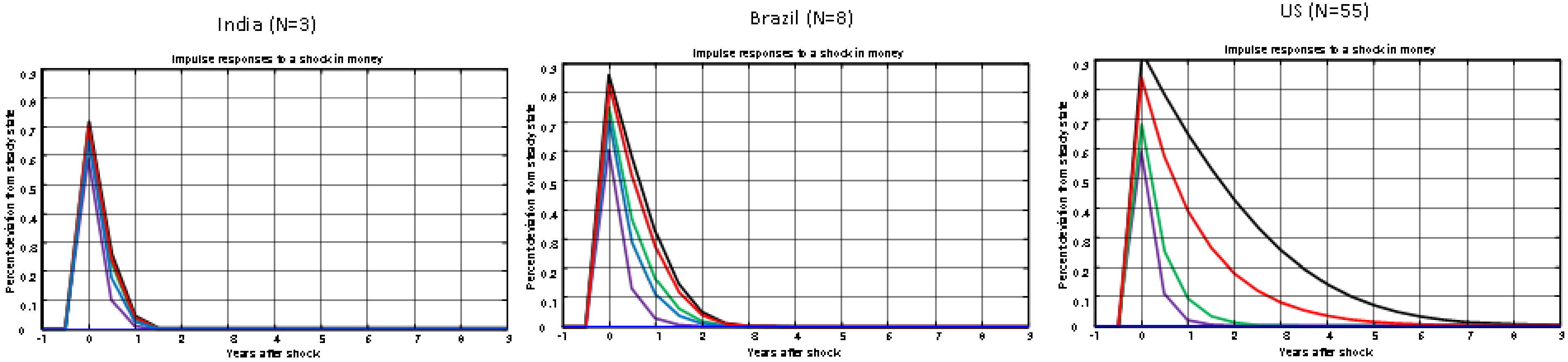



**Key:** — β (as calibrated), — β = 0.5, — β = 0.61, — β = 0.91, — β = 0.99

**Table 5.5** **Sensitivity of the Contract Multiplier and Half-Life of Output to β**

| | India (N=3) | | | | | Brazil (N=8) | | | | | US (N=55) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Calibrated β = 0.72 | β = 0.5 | β = 0.61 | β = 0.91 | β = 0.99 | Calibrated β = 0.61 | β = 0.5 | β = 0.61 | β = 0.91 | β = 0.99 | Calibrated β = 0.85 | β = 0.5 | β = 0.61 | β = 0.91 | β = 0.99 |
| **t = 0** | 0.690 | 0.724 | 0.714 | 0.676 | 0.669 | 0.752 | 0.768 | 0.752 | 0.714 | 0.705 | 0.695 | 0.725 | 0.711 | 0.679 | 0.672 |
| **1** | 0.224 | 0.271 | 0.249 | 0.205 | 0.196 | 0.368 | 0.401 | 0.368 | 0.297 | 0.282 | 0.271 | 0.326 | 0.300 | 0.243 | 0.231 |
| **2** | 0.034 | 0.047 | 0.041 | 0.029 | 0.027 | 0.163 | 0.190 | 0.163 | 0.112 | 0.102 | 0.106 | 0.147 | 0.127 | 0.087 | 0.080 |
| **3** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.062 | 0.077 | 0.062 | 0.036 | 0.031 | 0.041 | 0.066 | 0.054 | 0.031 | 0.027 |
| **Contract Multiplier ($Y_1$ /$Y_0$)** | 0.34 | **0.37** | 0.35 | 0.30 | 0.29 | 0.49 | **0.52** | 0.49 | 0.42 | 0.40 | 0.39 | **0.45** | 0.42 | 0.36 | 0.34 |
| **Half-Life (in months)** | 4.1 | **4.8** | 4.7 | 3.9 | 3.8 | 5.9 | **6.6** | 5.9 | 5.1 | 5.0 | 4.7 | **5.7** | 5.4 | 4.7 | 4.5 |

**Figure 5.6** Sensitivity of the Impulse Response of Output to γ




**Key:** — γ (as calibrated), — γ = 0.5, — γ = 0.76, — γ = 0.95, — γ = 0.99

**Table 5.6** Sensitivity of the Contract Multiplier and Half-Life of Output to γ

| | India (N=3) | | | | | Brazil (N=8) | | | | | US (N=55) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Calibrated γ = 0.90 | γ = 0.5 | γ = 0.73 | γ = 0.95 | γ = 0.99 | Calibrated γ = 0.83 | γ = 0.5 | γ = 0.73 | γ = 0.95 | γ = 0.99 | Calibrated γ = 0.79 | γ = 0.5 | γ = 0.73 | γ = 0.95 | γ = 0.99 |
| **t = 0** | 0.690 | 0.591 | 0.652 | 0.704 | 0.715 | 0.752 | 0.606 | 0.707 | 0.829 | 0.863 | 0.695 | 0.593 | 0.685 | 0.841 | 0.924 |
| **1** | 0.224 | 0.101 | 0.177 | 0.242 | 0.257 | 0.368 | 0.129 | 0.289 | 0.516 | 0.584 | 0.271 | 0.110 | 0.253 | 0.573 | 0.778 |
| **2** | 0.034 | 0.011 | 0.024 | 0.038 | 0.041 | 0.163 | 0.027 | 0.110 | 0.273 | 0.327 | 0.106 | 0.020 | 0.094 | 0.390 | 0.646 |
| **3** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.062 | 0.006 | 0.037 | 0.117 | 0.146 | 0.041 | 0.004 | 0.035 | 0.264 | 0.527 |
| **Contract Multiplier ($Y_1$ /$Y_0$)** | 0.32 | 0.17 | 0.27 | 0.34 | **0.36** | 0.49 | 0.21 | 0.41 | 0.62 | **0.68** | 0.39 | 0.19 | 0.37 | 0.68 | **0.84** |
| **Half-Life (in months)** | 4.4 | 3.6 | 4.2 | 4.5 | **4.8** | 5.8 | 3.9 | 5.1 | 8.7 | **9.6** | 4.8 | 3.6 | 4.8 | 10.8 | **21.9** |

### *5.5.3. The number of stages (N)*

This examines how the persistence of output changes as the number of stages (N) increases, N = {2, 3, 5, 8, 13, 21, 34, 55}, and how this is affected by changing the values of β and γ, both individually and simultaneously. The impulse response functions are presented in Figure 5.7 and the contract multipliers and half-lives are reported in Tables 5.7 and 5.8, respectively.

As expected, as the number of stages increases, the degree of output persistence generated by the model also increases. The extent of this increase is, however, dependent on the values of γ and β. As shown previously, the values of γ and β limit the degree of persistence generated by the model. Figure 5.7a reveals that, given the calibrated values of γ and β for the US, the model cannot generate any additional persistence beyond N=8. Therefore, the effect of increasing the number of stages is severely limited and it is clearly not enough to simply increase the value of N in order to generate increased persistence.

Figure 5.7b shows the impulse responses functions as N increases when the minimum calibrated value of β (0.61) is applied, instead of the calibrated value for the US. From this, it is clear that the reduction in the value of β has only a very small impact on the degree of output persistence. Increasing the number of stages only has an effect up to N=13; further increases in N make no difference to the impulse responses of output.

Figure 5.7c shows the impulse responses functions as N increases when the maximum calibrated value of γ (0.95) is applied, instead of the calibrated value for the US. In this case, it is clear that γ is highly significant for the degree of output persistence and increasing the value of N has a significant effect, which is not limited. This has important implications for the model. In particular, as discussed in Huang and Liu (2001), as $\gamma \to 1$ the persistence of output becomes infinite. Thus, money would have a permanent real effect on output.

Figure 5.7d shows the impulse response functions as N increases, when the maximum calibrated value of γ (0.95) and the minimum calibrated value of β (0.61) are simultaneously applied. It is obvious from this, that simultaneously lowering β and raising γ reinforces the individual effects and significantly increases the output persistence generated by the model. In this case the half-life of output increases to 15.4 months which is just short of that observed in the US economy (16.6 months). Thus, the model is clearly capable of generating empirically plausible output persistence values.

**Figure 5.7**

**Impulse Response Functions for the US: Impact of Changing β, γ and N**

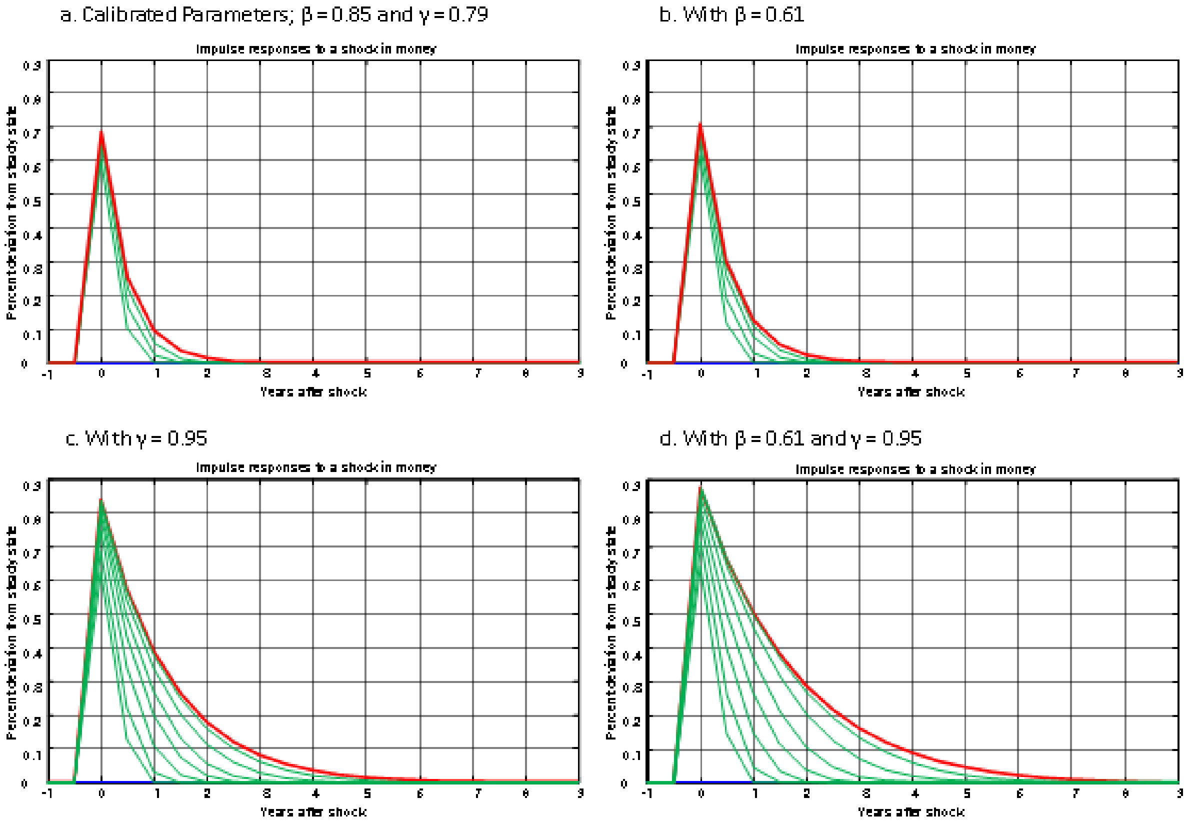



**Table 5.7** **Contract Multiplier ($Y_1$ /$Y_0$)**

| N = | 2 | 3 | 5 | 8 | 13 | 21 | 34 | 55 |
|---|---|---|---|---|---|---|---|---|
| Calibrated Parameters | 0.17 | 0.25 | 0.33 | 0.37 | 0.39 | 0.39 | 0.39 | **0.39** |
| With β = 0.61 | 0.19 | 0.29 | 0.37 | 0.41 | 0.42 | 0.42 | 0.42 | **0.42** |
| With γ = 0.95 | 0.20 | 0.32 | 0.45 | 0.55 | 0.61 | 0.65 | 0.67 | **0.68** |
| With β = 0.61 and γ = 0.95 | 0.23 | 0.36 | 0.51 | 0.62 | 0.69 | 0.73 | 0.75 | **0.76** |

**Table 5.8** **Half-Life (in months)**

| N = | 2 | 3 | 5 | 8 | 13 | 21 | 34 | 55 |
|---|---|---|---|---|---|---|---|---|
| Calibrated Parameters | 3.6 | 4.1 | 4.3 | 4.7 | 4.8 | 4.8 | 4.8 | **4.8** |
| With β = 0.61 | 3.6 | 4.2 | 4.8 | 5.2 | 5.4 | 5.5 | 5.5 | **5.5** |
| With γ = 0.95 | 3.6 | 4.3 | 5.5 | 7.2 | 8.4 | 9.8 | 10.6 | **10.9** |
| With β = 0.61 and γ = 0.95 | 3.9 | 4.8 | 6.2 | 8.4 | 10.3 | 12.7 | 14.4 | **15.4** |

## 5.6. EMPIRICAL RESULTS

This section presents results from simulating the model for the calibrated countries. It evaluates how successful the model is in: (i) reproducing the observed half-lives for the calibrated countries; and (ii) capturing the patterns of output persistence observed in section 5.2; namely the positive relationship between economic development and output persistence.

### *5.6.1 Impulse Response Functions*

To compute the impulse responses, the value of the innovation term ($\varepsilon_t$) in the money growth process (5.26) at time zero is set equal to one ($\varepsilon_0 = 1$), so that the money stock rises by one-percent one year after the shock. For all $t \geq 1$, the innovation term is set equal to zero.

Figure 5.8 displays the impulse responses of output for the US, UK and Japan; Figure 5.9 displays the impulse responses for the calibrated Asian countries (India, South Korea, Malaysia, the Philippines and Turkey); Figure 5.10 displays the impulse responses for the calibrated Latin American countries (Argentina, Brazil, Chile, Colombia, Mexico and Peru); Figure 5.11 displays the impulse responses for the calibrated Eastern European countries (Hungary, Lithuania, Slovenia and Slovak Republic); and Figure 5.12 displays the impulse responses for the calibrated African countries (Israel and South Africa).

**Figure 5.8**

**Impulse Responses of Aggregate Output for (a) the US, (b) Japan and (c) the UK**

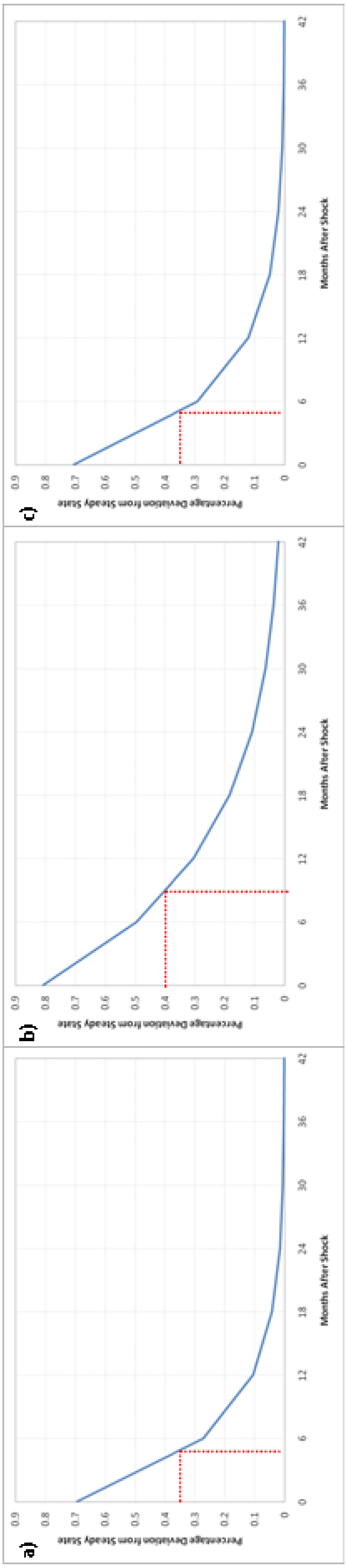


**Figure 5.9**

**Impulse Responses of Aggregate Output for (a) India, (b) South Korea, (c) Malaysia, (d) the Philippines and (e) Turkey**

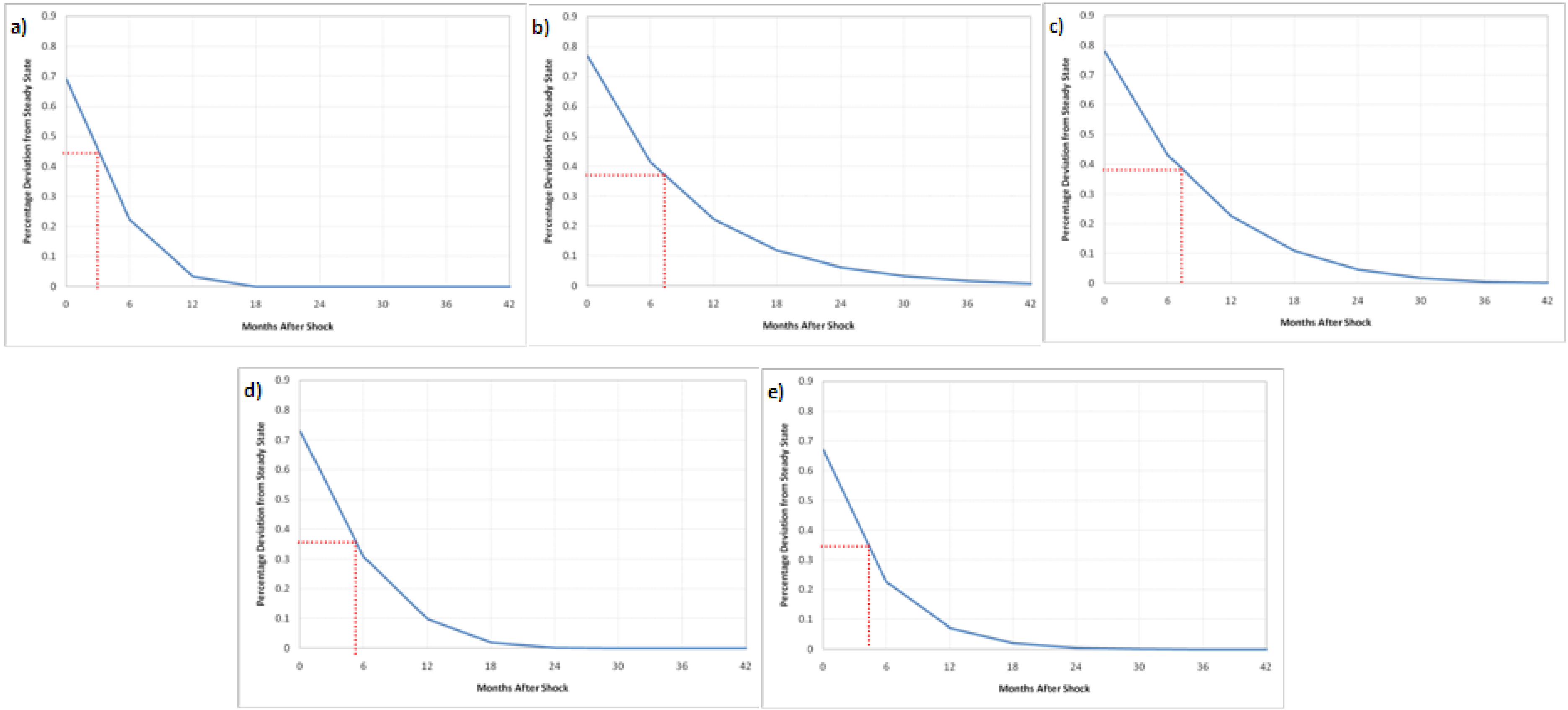


**Figure 5.10**

**Impulse Responses of Aggregate Output for (a) Argentina, (b) Brazil, (c) Chile, (d) Colombia, (e) Mexico and (f) Peru**

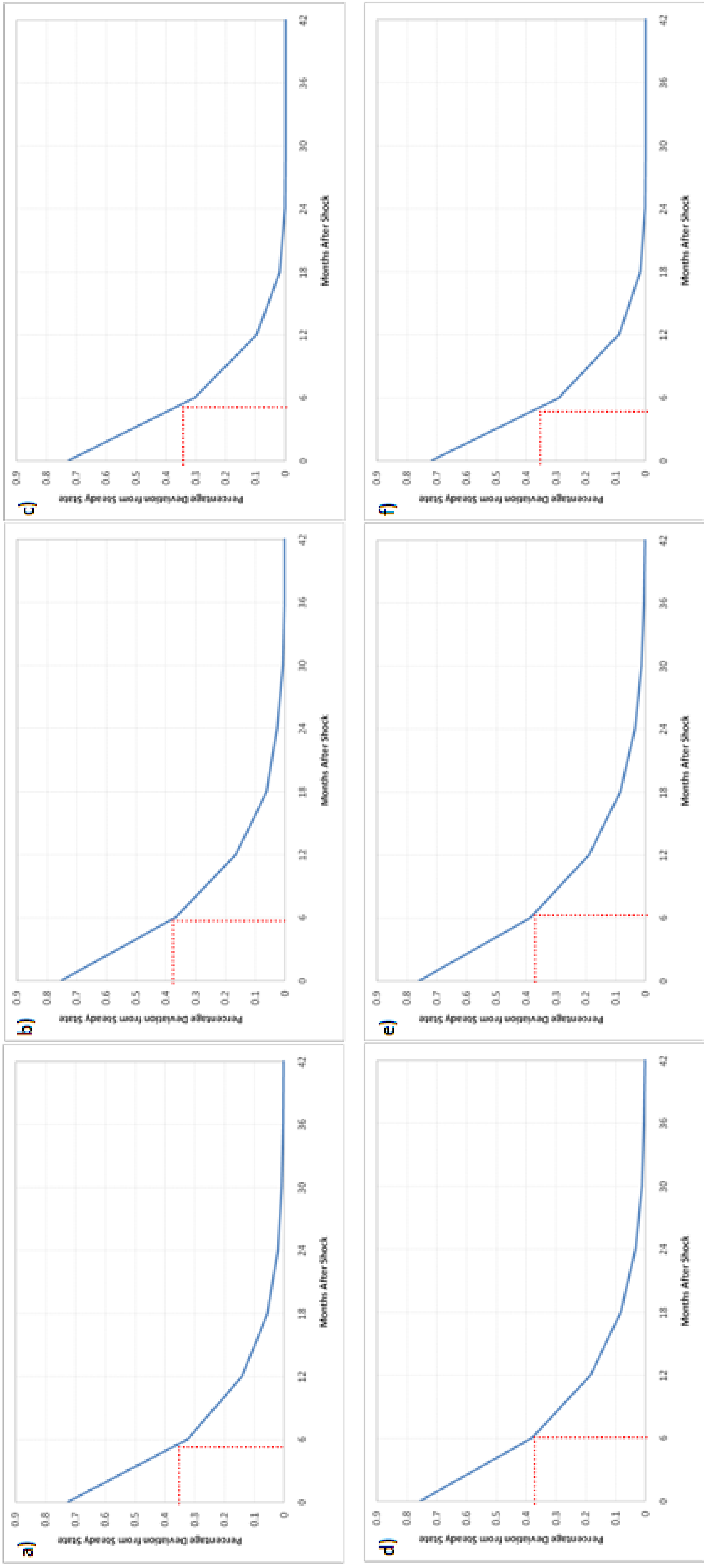


Figure 5.11

Impulse Responses of Aggregate Output for (a) Hungary, (b) Lithuania, (c) Slovenia and (d) the Slovak Republic

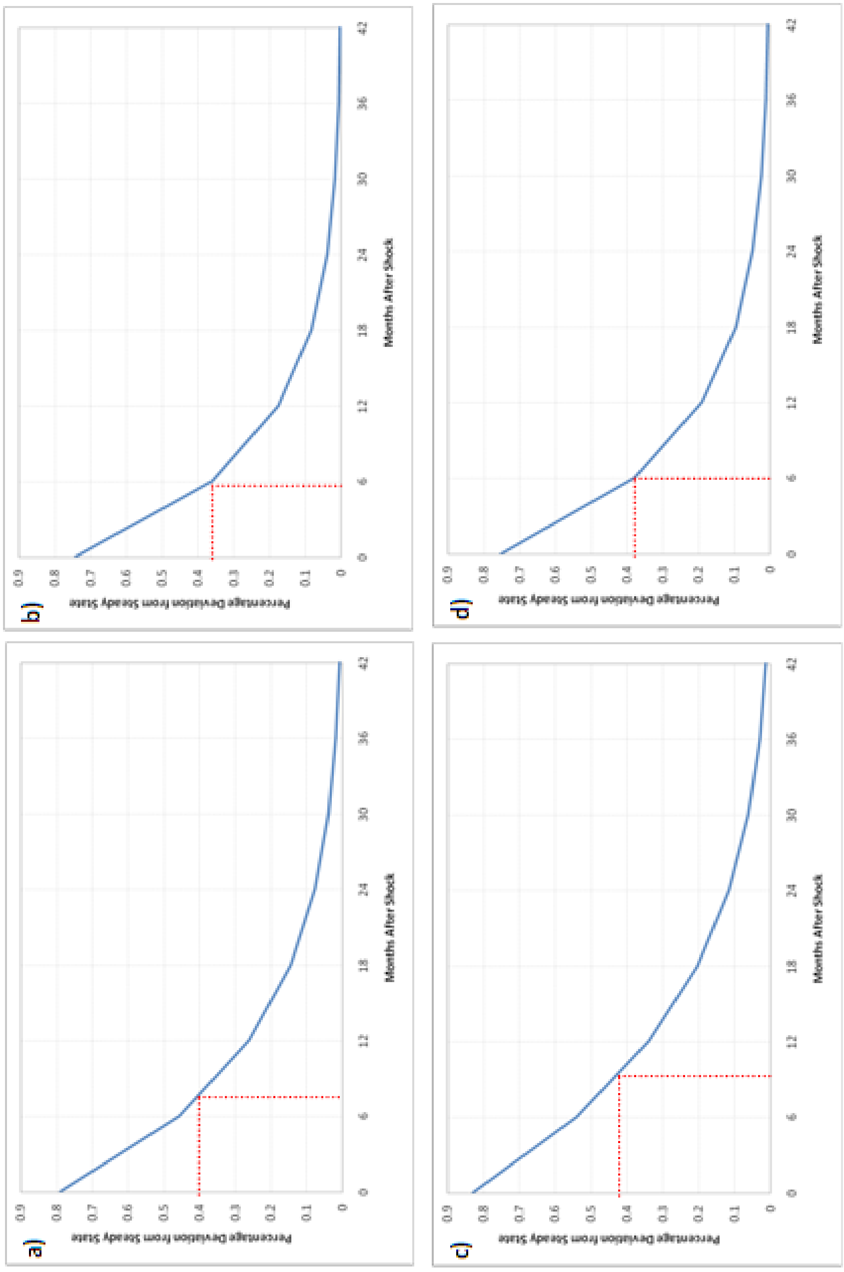
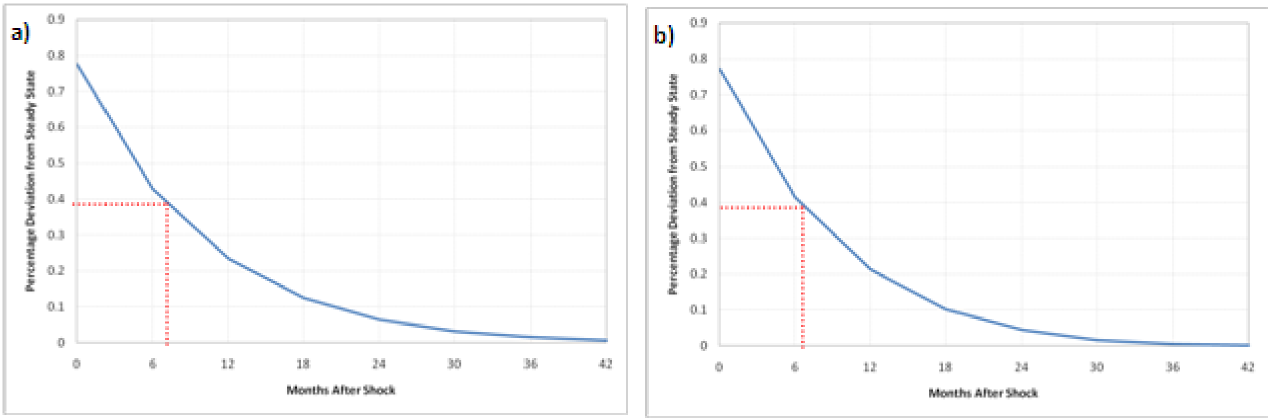


**Figure 5.12**

**Impulse Responses of Aggregate Output for (a) Israel and (b) South Africa**



To allow for further examination, the magnitude of persistence for each of these countries is measured using both the half-life of output and the contract multiplier; these values are detailed in Table 5.9.

**Table 5.9** **Estimated Half-Lives and Contract Multipliers**

| Country | N | Half-Life (model) (months) | Contract Multiplier ($Y_1/Y_0$) |
|---|---|---|---|
| India | 3 | 4.4 | 0.32 |
| Colombia | 5 | 5.2 | 0.42 |
| Peru | 5 | 5.0 | 0.40 |
| Philippines | 5 | 5.2 | 0.42 |
| Brazil | 8 | 5.8 | 0.49 |
| Turkey | 8 | 4.4 | 0.34 |
| Argentina | 13 | 5.4 | 0.45 |
| Chile | 13 | 6.0 | 0.50 |
| Malaysia | 13 | 7.2 | 0.44 |
| Mexico | 13 | 6.1 | 0.51 |
| South Africa | 13 | 6.7 | 0.54 |
| Hungary | 21 | 7.6 | 0.58 |
| Israel | 21 | 7.2 | 0.55 |
| Lithuania | 21 | 5.9 | 0.49 |
| Slovak Republic | 21 | 6.0 | 0.50 |
| Japan | 34 | 8.9 | 0.61 |
| Korea, South | 34 | 7.0 | 0.54 |
| Slovenia | 34 | 9.6 | 0.65 |
| UK | 34 | 5.2 | 0.41 |
| US | 55 | 4.8 | 0.39 |

The central premise of Huang and Liu (2001) is that the greater the number of production stages (N), the more persistent the response of output. However, initial examination of the impulse response functions and half-life estimates suggests that, for these countries, this relationship is weak at best. Figure 5.13(a) plots the relationship between N and the half-life (in months).

Examination reveals that there are two notable exceptions to such a positive trend, namely the US and the UK; both of these countries are highly economically developed and consequently have high N values, and yet the model generates very little output persistence. Exclusion of the US and UK from the analysis yields a significant strong positive relationship between N and the half-life (in months), as conjectured in Huang and Liu (2001); this is shown in Figure 5.13(b).

To explain this lack of persistence, it is necessary to turn to the sensitivity analysis of section 5.5; this revealed that the most important parameter in determining the magnitude of output persistence is the share of the composite of stage n-1 goods in i's production (γ). Thus, the diminutive half-lives can be explained to some extent by the calibration from the data of extremely low gamma values; 0.78 and 0.79 respectively. These values effectively inhibit the model from generating any significant degree of output persistence for either the US or the UK.

In order to further examine the relationship between N and the degree of output persistence generated by the model, the consistency of the gamma values are investigated in light of the associated literature. Basu and Fernald (1997) estimate the average steady state mark-up of price over marginal cost (μ) for US industries to be 1.08, whilst Brandt (2007) estimates the mark-up for a number of OECD countries, from which the average for US industries is 1.23. Combining these mark-up values with the values for the share of intermediate goods in total manufacturing (η) and the steady-state unit cost (υ) for US manufacturing industries as calibrated in section 5.3, produces a value of γ between 0.816 (when μ=1.08) and 0.929 (1.23); both of which are significantly higher than the values of γ calibrated directly from the input-output tables. Consequently, the average of these two values, namely γ = 0.87, is taken and the simulations are repeated for both the US and UK. As expected, the higher gamma values enable the model to generate a much greater half-life of output for both of these countries; for the UK the half-life of output increases from 5.2 months to 6.6 months, whilst for the US the half-life increases from 4.8 months to 6.4 months.

Further examination of the relationship between N and the half-life (in months) with the new half-life values for the US and UK, yields a considerably stronger positive relationship; this is shown in Figure 5.13(c). However, the degree of persistence generated for the US still remains an outlier; this is because, given the value of gamma (γ = 0.87), the model is unable to generate any additional persistence beyond N = 34 (the half-life when the model is run with 34 stages and the half-life when the model is run with all 55 stages is identical).

**Figure 5.13(a)**

**Relationship between Half-Life (in months) and Number of Stages (N); all countries**

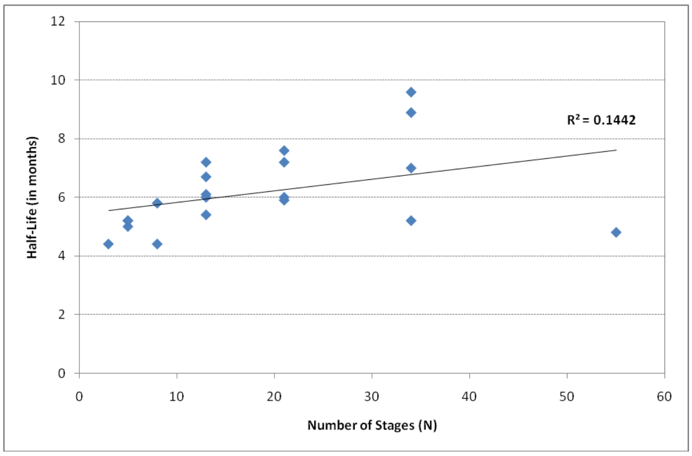



**Figure 5.13 (b)**

**Relationship between Half-Life (in months) and Number of Stages (N); excluding the UK and US**

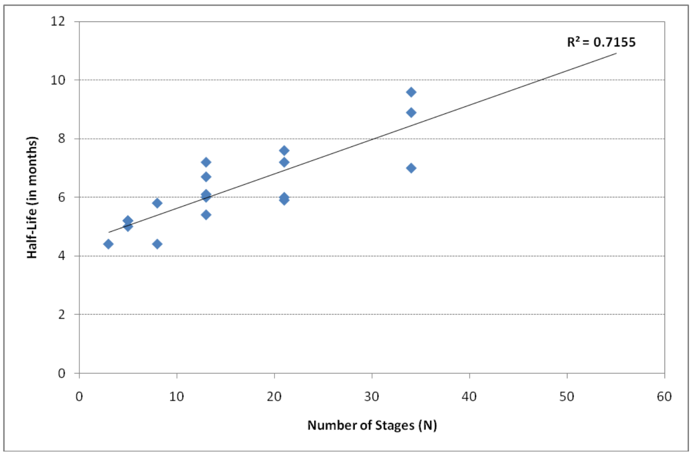
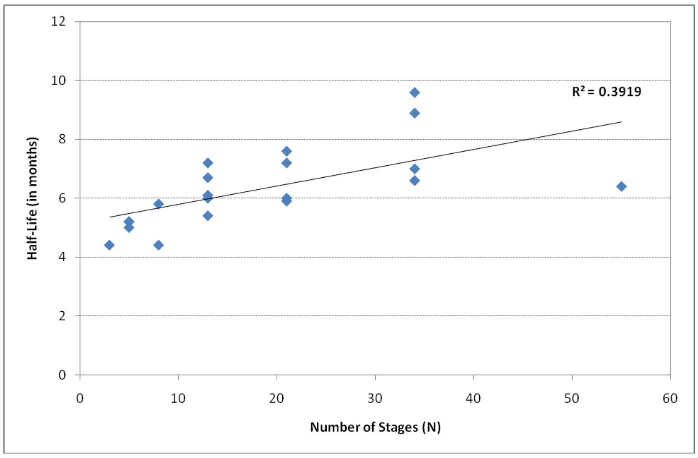



**Figure 5.13 (c)**

**Relationship between Half-Life (in months) and Number of Stages (N); including the UK and US with gamma = 0.87**



### *5.6.2. Relationship to Actual Output Persistence*

Having established that there is a positive relationship between the number of production stages (N) and the magnitude of output persistence, the next step is to examine how successful the model is in reproducing the observed half-lives for the calibrated countries. Table 5.10 details the half-life of output (as estimated from the actual data), the half-life of output (as estimated from the impulse response function), and the difference between the two half-lives.

**Table 5.10 Relationship between Model and Actual Output Persistence**

| Country | N | Half-Life: Data (months) | Half-Life: Model (months) | Difference |
|---|---|---|---|---|
| US | 55 | 16.6 | 4.8 | 11.8 |
| Japan | 34 | 9.9 | 8.9 | 1.0 |
| UK | 34 | 11.1 | 5.2 | 5.9 |
| Argentina | 13 | 4.5 | 5.4 | -0.9 |
| Brazil | 8 | 2.7 | 5.8 | -3.1 |
| Chile | 13 | 7.8 | 6.0 | 1.8 |
| Colombia | 5 | 3.7 | 5.2 | -1.5 |
| Hungary | 21 | 9.8 | 7.6 | 2.2 |
| India | 3 | 4.4 | 4.4 | 0.0 |
| Israel | 21 | 6.3 | 7.2 | -0.9 |
| Korea, South | 34 | 9.3 | 7.0 | 2.3 |
| Lithuania | 21 | 3.3 | 5.9 | -2.6 |
| Malaysia | 13 | 7.5 | 7.2 | 0.3 |
| Mexico | 13 | 5.8 | 6.1 | -0.3 |
| Peru | 5 | 4.6 | 5.0 | -0.4 |
| Philippines | 5 | 5.8 | 5.2 | 0.6 |
| Slovak Republic | 21 | 4.9 | 6.0 | -1.1 |
| Slovenia | 34 | 10.6 | 9.6 | 1.0 |
| South Africa | 13 | 9.4 | 6.7 | 2.7 |
| Turkey | 8 | 4.3 | 4.4 | -0.1 |

Looking at Table 5.10, it is possible to see that in most cases the model generates a half-life which is reasonably close to the half-life of the actual data; in fact, for 90% of the countries, the estimated half-life is within one quarter of the actual half-life. The two exceptions, as discussed in the previous section, are the US and the UK. However, at first glance, there is no clear pattern as to whether the model over- or underestimates the degree of output persistence.

Section 5.2 revealed that there is a strong positive relationship between level of economic development, as measured by GDP per capita and energy use per capita, and the persistence of output fluctuations. This is consistent with the positive relationship between the number of stages of production (N) and the estimated half-life for the model. Furthermore, there is another salient feature of countries' output persistence, namely that output fluctuations are less persistent in high inflation countries; this is notably documented by Kiley (2000). This characteristic provides another angle to examine the relationship between a country's actual output persistent and the model's estimated output persistence. As the model does not account for inflation, it is feasible that the magnitude of output persistence for countries with low inflation rates may be underestimated, whilst the output persistence of high inflation countries may be overestimated.

Table 5.11, details the relationship between inflation and the difference between real and model half-life. Inflation data is taken from the World Bank World Development Indicators, (series: inflation, consumer prices, annual %), from which the average annual inflation rate over the period 1980 to 2005 is calculated for each country. Average annual inflation rate is classified as being high when the annual rate exceeds 15% and as low when it is below 15%; such a classification is consistent with the literature, for example Kakkar and Ogaki (2002) rank inflation as high when it is greater than 10%, medium between 5 and 10% and low when it is below 5%, whilst Gagnon (2009) classifies high inflation as anything above 10-15% and low inflation as anything below 10-15%.

**Table 5.11**

**Relationship between Inflation and the Difference between Real and Model Half-Life**

| Country | Average Annual Inflation Rate (%) (1980 – 2005) | Inflation Ranking | Difference (Actual Half-Life *minus* Model Half-Life) |
|---|---|---|---|
| **Brazil** | 432.66 | HIGH | -3.1 |
| **Lithuania** | 38.41 | HIGH | -2.6 |
| **Colombia** | 18.15 | HIGH | -1.5 |
| **Slovak Republic** | 7.23 | LOW | -1.1 |
| **Argentina** | 294.90 | HIGH | -0.9 |
| **Israel** | 50.76 | HIGH | -0.9 |
| **Peru** | 461.05 | HIGH | -0.4 |
| **Mexico** | 33.44 | HIGH | -0.3 |
| **Turkey** | 53.74 | HIGH | -0.1 |
| **India** | 7.97 | LOW | 0 |
| **Malaysia** | 3.18 | LOW | 0.3 |
| **Philippines** | 9.96 | LOW | 0.6 |
| **Japan** | 1.24 | LOW | 1.0 |
| **Slovenia** | 9.47 | LOW | 1.0 |
| **Chile** | 12.71 | LOW | 1.8 |
| **Hungary** | 12.95 | LOW | 2.2 |
| **Korea, South** | 5.90 | LOW | 2.3 |
| **South Africa** | 10.27 | LOW | 2.7 |
| **United Kingdom** | 4.78 | LOW | 5.9 |
| **United States** | 3.85 | LOW | 11.8 |

Looking at Table 5.11, there is a very clear relationship between inflation and the difference between a country's actual half-life and the model's estimated half-life: where the model overestimates a country's half-life, the country has high inflation, whilst where the model underestimates a country's half-life, the country has low inflation. There is just one exception to this; the Slovak Republic, which has low inflation and yet the model overestimates the degree of output persistence. Referring to the calibrations, it is evident that Slovak Republic has an exceedingly high gamma value which, given the model's sensitivity to the value of gamma, may explain the overestimation of output persistence.

Table 5.11 also reveals that three of the Latin American economies, Argentina, Brazil and Peru, had extremely high average annual inflation rates over the sampling period. Examining this in the case of Peru, it is evident that the country suffered from very high inflation between 1980 and 1993, reaching a peak of almost 3400% in 1989, whilst from 1994 onwards, the inflation rate was low; average annual inflation rate for 1993 to 2005 was just 5.9%. This provides an opportunity to further investigate the conjecture that the model overestimates the magnitude of output persistence in high inflation countries whilst underestimating the magnitude of output persistence for low inflation countries. Calculating the half-life of output for Peru for the low inflation period (1994:1 – 2005:1) and comparing this to the model half-life, yields a difference of +0.5,[13] whilst for the high inflation period (1980:1 – 1993:4) the difference between model and actual half-life is -0.6.[14] Thus, these results further corroborate the relationship between inflation and the difference between real and model half-life.

Econometric analysis of this relationship was carried out using the least squares dummy variable (LSDV) method. Two dummy variables were created, high and low;

$High_i$ = 1 if the country i's average inflation rate exceeds 15%
= 0 otherwise
$Low_i$ = 1 if the country i's average inflation rate is below 15%
= 0 otherwise

Following the previous discussion, Peru was considered as a low inflation country and the difference between actual half-life for the period 1994:1 – 2005:1 and model half-life was used. The regression is run in STATA using the LSDV1 method, which drops one of the

[13] To estimate the half-life for the period 1994:1–2005:1 an ARMA(1,1) model was fitted to the data, giving a half-life of 5.5 months. The Ljung-Box Q statistic indicated that the residuals were not serially correlated at the 1% level (Q = 28.26).
[14] To estimate the half-life for the period 1980:1–1993:4 an ARMA(1,2) model was fitted to the data, giving a half-life of 4.4 months. The Ljung-Box Q statistic indicated that the residuals were not serially correlated at the 1% level (Q = 24.77).

dummy variables, Low in this case, to ensure that the model is identified. This method ensures that the $R^2$ and F statistics obtained from the regression are correct. Table 5.12 details the regression results.[15]

**Table 5.12 Regression Results: Relationship between Difference and Inflation**

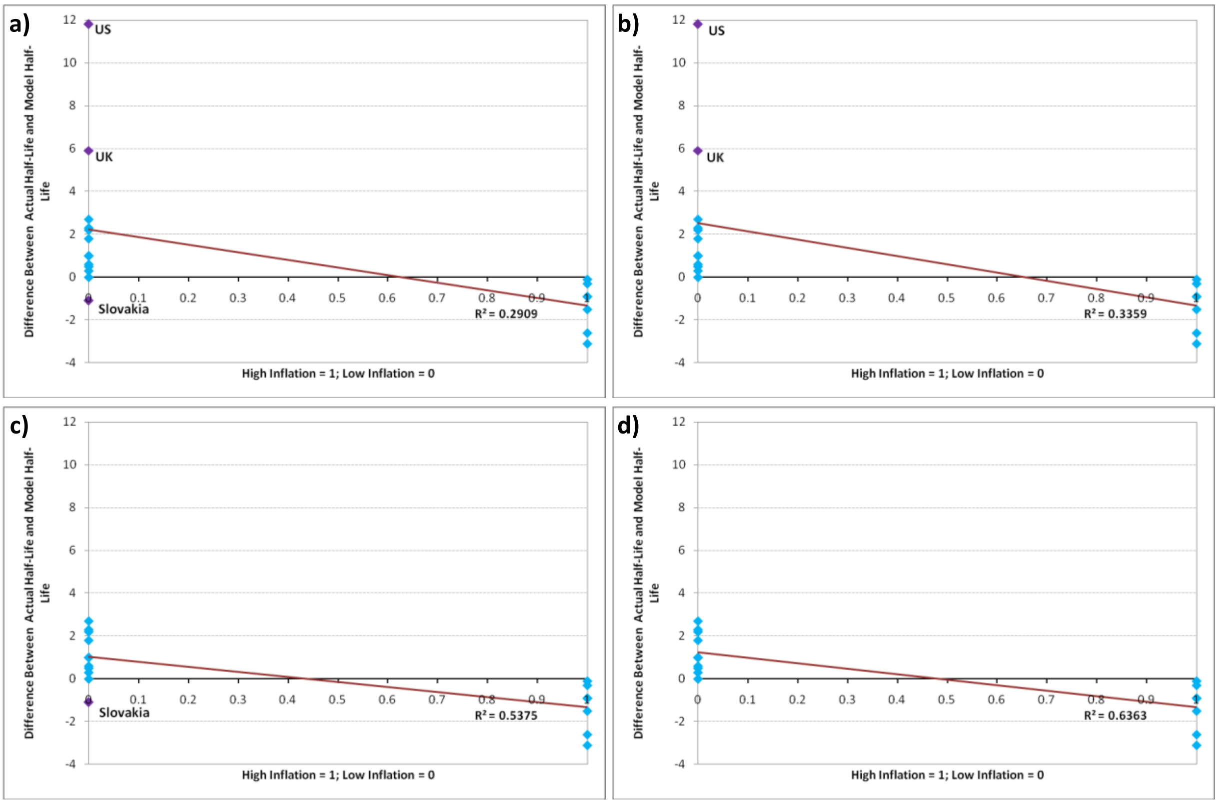
| | A | B | C | D |
|---|---|---|---|---|
| HIGH | -3.574* (1.315) | -3.851** (1.313) | -2.370** (0.550) | -2.583** (0.504) |
| Constant | 2.231** (0.778) | 2.508** (0.797) | 1.027** (0.343) | 1.240** (0.324) |
| $R^2$ | 0.291 | 0.336 | 0.538 | 0.636 |
| F | 7.38* | 8.60** | 18.95** | 26.24** |

Significance is denoted by: * if p<0.05 and ** if p<0.01
Standard errors are reported in brackets.

A: All countries are included in the regression
B: Slovak Republic is excluded from the regression
C: The US and UK are excluded from the regression
D: The US and UK and Slovak Republic are excluded from the regression

**Figure 5.14**

**Graphical Representation of Regression Results; (a) all countries, (b) excluding Slovak Republic, (c) excluding the US and UK, (d) excluding Slovak Republic, the US and UK**




[15] Diagnostics and residual plots are available in Appendix E.

With all of the countries included in the regression the relationship is weak, although it is still significant at the 95% level. This weak result can be explained partly by the inclusion of Slovak Republic; as previously discussed, the calibration of an extremely high gamma value for Slovak Republic causes the model to overestimate the country's inflation. The remaining weakness can be explained by the inclusion of the US and the UK. Although these two countries follow the general pattern, they have low inflation and the model underestimates the half-life, they are outliers in that the difference between actual and model half-life is much greater than for any of the other countries. As previously discussed, both the US and the UK are highly economically developed countries and have correspondingly high levels of output persistence, however the calibration of low gamma values for both countries inhibits the model from generating anywhere near the degree of output persistence that is necessary to match the data.

Removing each of the outliers in turn significantly strengthens the relationship between inflation and the over/underestimation of the country's half-life. Figure 5.14(d) clearly shows that, in the absence of the outliers, the model overestimates output persistence for countries with high inflation and underestimates output persistence for countries with low inflation.

One possible criticism of this analysis is that there could be a systematic difference in the response of output to supply shocks that might explain the difference between actual and model half-life, rather than inflation. However, Kiley (2000) reveals that the lack of persistence in high inflation economies is not the result of less persistent aggregate supply or demand shocks, less-persistent nominal output fluctuations or greater variability of nominal output, greater openness of the economy or inflation crises. Thus, Kiley (2000) concludes that the results are "*supportive of less-persistent output fluctuations in high-inflation economies, as predicted by an endogenous price stickiness model*" (p.51)

The only significant explanatory variable identified in Kiley (2000) is that of income per capita. However, as revealed in this analysis, there is a strong positive relationship between persistence and economic development, and therefore such a relationship is to be expected.

### *5.6.3. Relationship to Economic Development*

The analysis in section 5.2.3 demonstrated that there is a clear positive relationship between economic development, as measured by GDP per capita and energy use per capita, and output persistence. Thus, it is now interesting to investigate how successful the model is in replicating this pattern.

It is assumed that the more economically developed an economy, the more sophisticated the input-output structure. Therefore, the more economically developed the countries in the sample, the greater the number of stages in the input-output structure (N) they were assigned. Examination of the relationship between N and the degree of output persistence generated by the model revealed, with the exception of the US and the UK, a significant strong positive relationship. This is consistent with both the finding of greater output persistence in more economically developed countries and the central proposition of Huang and Liu (2001) that the greater the number of production stages (N), the more persistent the response of output.

For completeness, the relationship between the magnitude of output persistence generated by the model and the values of GDP per capita and energy use per capita is examined. Table 5.13 details the regression results and Figures 5.15 and 5.16 demonstrate this graphically. As anticipated from previous analysis in this section, the US and UK are significant outliers and are abstracted from accordingly. Furthermore, because of the multicollinearity between GDP per capita and energy use per capita, the full regression model with both predictors is not considered here.

**Table 5.13 Relationship between Model Half-Life and Economic Development**

| | Model 1 | | Model 2 | |
|---|---|---|---|---|
| | A | B | A | B |
| Ln[GDP] | 0.942* (0.373) | 1.611** (0.310) | | |
| Ln[Energy Use] | | | 0.883* (0.353) | 1.468** (0.301) |
| Constant | -2.623 (3.497) | -8.542** (2.871) | -0.491 (2.678) | -4.600 (2.248) |
| $R^2$ | 0.262 | 0.627 | 0.258 | 0.598 |
| F | 6.38* | 26.91** | 6.27* | 23.79* |

Significance is denoted by: * if p<0.05 and ** if p<0.01
Standard errors are reported in brackets.

A: All countries are included in the regression
B: The US and UK are excluded from the regression

These results show that, whilst there is only a weak positive relationship between the magnitude of output persistence generated by the model and economic development when all countries are included in the analysis, this becomes a strong significant positive relationship upon the exclusion of the US and the UK. This suggests that, amongst the developing countries at least, the model is successful in replicating the observed patterns of output persistence across countries at different levels of development.

**Figure 5.15 Relationship between Model Half-Life and GDP per capita (PPP, 2005); (a) all countries, (b) excluding the US and UK**

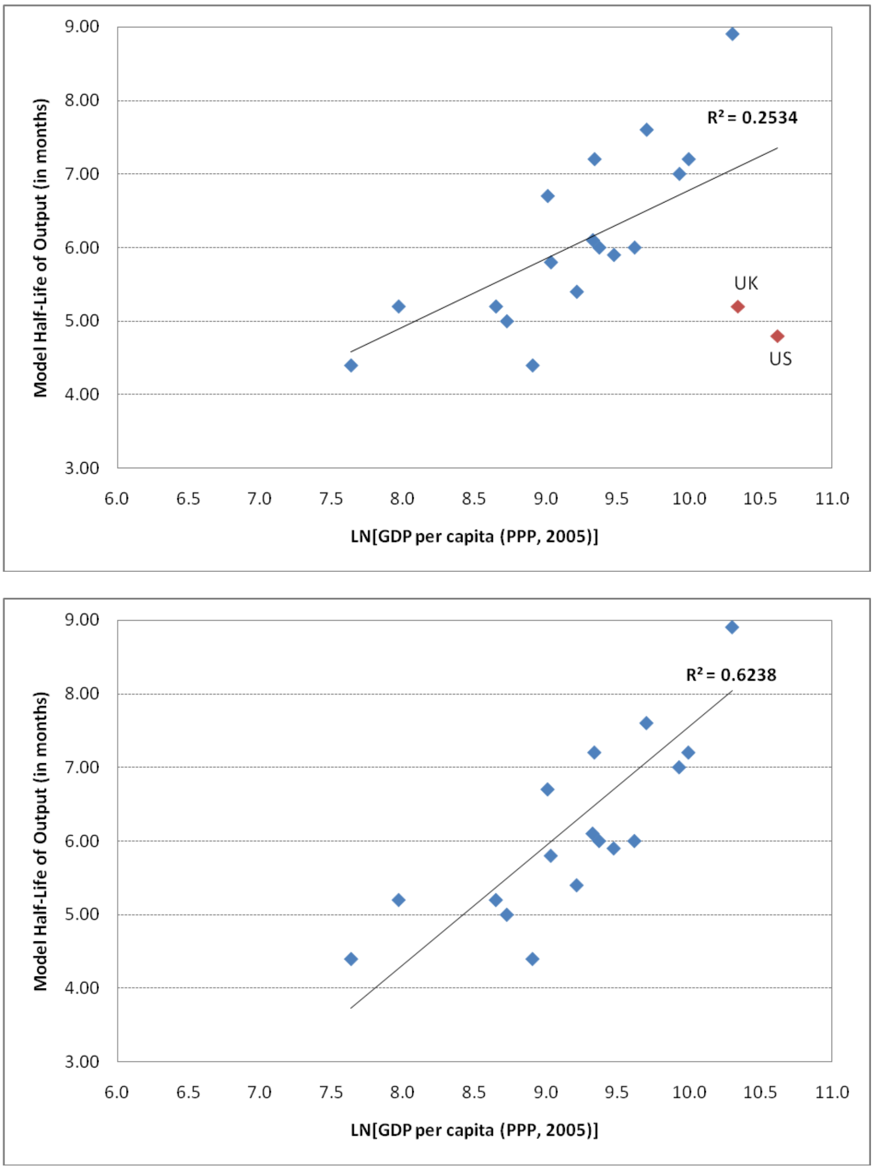
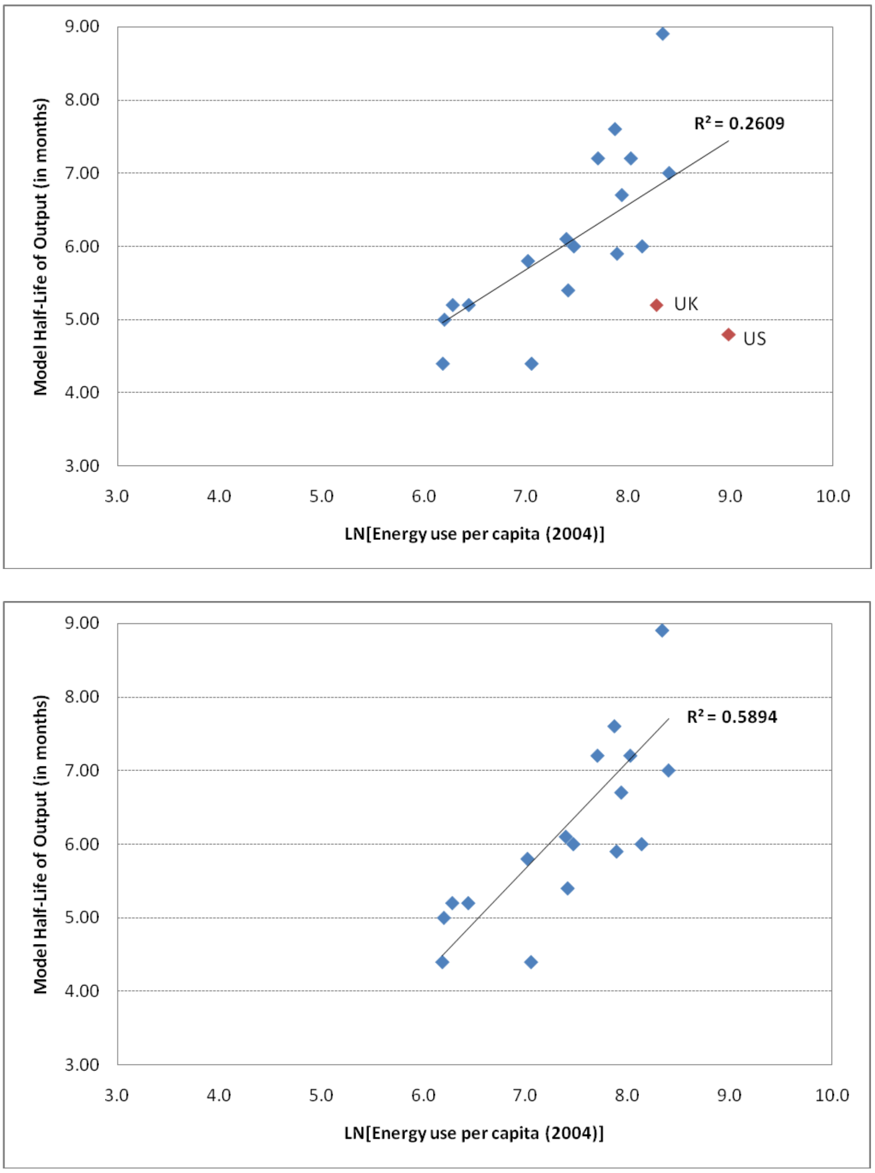


**Figure 5.16 Relationship between Model Half-Life and Energy Use per capita (2004); (a) all countries, (b) excluding the US and UK**




## 5.7. CONCLUSION

This chapter has shown that there is a close relationship between output persistence and level of economic development, with more economically developed countries exhibiting much higher output persistence than less developed countries. This relationship was explored through the use of the Huang and Liu (2001) model. The vertical input-output structure embedded in this model enabled the representation of countries at various levels of economic development, from India to the US, simply by altering the number of production stages (N).

The model was calibrated for 20 countries at varying levels of economic development, and the results support the key premise of Huang and Liu (2001), namely that there is a strong positive relationship between the number of production stages and the magnitude of output persistence. Furthermore, sensitivity analysis revealed that the model is capable of generating output persistence anywhere between 3.6 months and 15.4 months; thus, it is clearly capable of representing both the most developed of countries, for example the US with a half-life of 16.6 months, and the least developed, for example India with a half-life of 4.4 months.

However, the effect of increasing the number of stages is severely limited by the share of the composite of stage n-1 goods in i's production ($\gamma$). This was particularly poignant in the modelling of the US and UK. Both countries are highly economically developed and had correspondingly high N values; however, calibration gave low values of $\gamma$ which effectively inhibited the model from generating any significant degree of output persistence for either country. Nonetheless, after abstracting from the US and UK results, there was found to be a strong significant positive relationship between the magnitude of output persistence generated by the model and economic development.

A very significant finding of this analysis is that the model overestimates output persistence in high inflation countries and underestimates output persistence in low inflation countries. This has important implications not only for this model, but also for any economist attempting to construct a business cycle model capable of replicating the observed patterns of output persistence. It may be possible to account for this inflation dichotomy by increasing the degree of price stickiness in low inflation countries, perhaps by increasing the number of price setting cohorts, and conversely by decreasing the degree of price stickiness in high inflation economies. In the context of the Huang and Liu (2001) model, each country would then not only be ranked according to level of economic development and assigned a corresponding N value, but would also be ranked according to whether they have high or low inflation and correspondingly assigned either two or four cohorts of price setters. This should significantly improve the fit of the model to countries' observed output persistence.

# CHAPTER 6

*"Summary and Conclusions"*

## 6.1. GENERAL CONCLUSIONS

Identifying business cycle stylised facts is essential as these are used for the construction and validation of theoretical business cycle models. Furthermore, understanding the cyclical patterns in economic activity, and their causes, is important to the decisions of both policymakers and market participants. This is of particular concern in developing countries where, in the absence of full risk sharing mechanisms, the economic and social costs of swings in the business cycle are very high.

The first set of stylised facts for industrialised countries was established by Kydland and Prescott (1990). This led to a burgeoning of literature freshly interested in the statistical properties of business cycles. The business cycles examined in this literature are known as growth cycles. Subsequent seminal papers by Harding and Pagan (2001, 2002 and 2006) and McDermott and Scott (1999) re-awakened the interest in *classical* cycles.

However, the literature extending from both of these strands of business cycle research predominantly concentrates on the business cycles of industrialised countries. A noticeable exception to this is the seminal paper by Agénor, McDermott and Prasad (2000), which established a set of stylised facts for the business cycles of developing countries. This was followed by a number of papers looking at developing countries, such as Rand and Tarp (2002), Neumeyer and Perri (2005) and Aguar and Gopinath (2007). There has also been a surge in papers examining the *classical* cycles of developing countries, notably Cashin (2004), Du Plessis (2006) and Calderon and Fuentes (2006).

Consequently, the knowledge of developing country business cycles is expanding. However, the majority of these papers have remarkably small data sets. For example, Agénor *et al.* (2000) have a sample of twelve middle-income countries, Rand and Tarp (2002) have fifteen, whilst Neumeyer and Perri (2005) have only five developing countries in their sample. Consequently, the results are subjective and dependent on the chosen countries, and thus cannot be used to provide an overall picture for the features of developing country business cycles.

Motivated by importance of these business cycle statistics and the lack of consistency amongst previous researchers, this thesis makes an important contribution to the literature by extending and generalising the developing country stylised facts. It examines both *classical* and *growth* cycles for a sample of thirty-two developing countries, plus the United Kingdom, the United States and Japan as developed country benchmarks.

This analysis yields the following stylised facts for developing country business cycles:

Firstly, business cycles in developing countries are not, as previously believed, significantly shorter than those of developed countries. This is a particularly significant result, because it justifies the use of the same smoothing parameter for both developing and developed countries when applying the Hodrick-Prescott (HP) filter (Hodrick and Prescott, 1997) to detrend time series data.

Secondly, fluctuations in output are, on average, twice as volatile in developing countries than in developed countries. Furthermore, output volatility is greatest amongst the least developed economies; this reflects the vulnerability of these economies and the inability to diversify risks or perform stabilising macroeconomic policy. Consequently, the high volatility is reflected in poor GDP growth rates.

Corresponding to this macroeconomic volatility, the amplitudes of both expansion and contraction phases of the developing country *classical* business cycle are significantly greater than in the developed countries. The Asian countries have the greatest expansion phase amplitude, whilst the African and Eastern European countries have the greatest contraction phase amplitudes. This corresponds with both the rapid rates of economic growth experienced by most Asian countries in the second half of the twentieth century, and with the consistently poor growth rates of the African and East European countries.

Thirdly, with the exception of the Latin American countries, the volatility of prices and wages are similar to those of the developed countries. There is no clear pattern of either pro- or countercyclicality of either prices or inflation amongst the developing countries. However, there is a tendency for those developing countries with countercyclical CPI to also exhibit countercyclical inflation and vice versa. This is a significant difference from the pattern of procyclical inflation and countercyclical prices observed in the industrialised countries. Real wages, however, are procyclical for both developing and developed countries. This has important implications for the choice of business cycle model; in particular, it is consistent with the application of a New Keynesian model with countercyclical mark-ups.

Fourthly, consistent with the previous literature, consumption and investment are significantly more volatile than in developed countries, although they are similarly procyclical. Consumption is on average 30% more volatile than output, whilst investment is between two and four times more volatile than output.

Fifthly, government revenue and expenditure are, on average, four times more volatile than output, which is significantly more volatile than in developed countries. The fiscal impulse is significantly countercyclical for the majority of the developing countries; this implies that fiscal policy is having a stabilising effect on business cycle fluctuations.

Sixthly, real interest rates are, on average, weakly procyclical in developing countries, not countercyclical as previously reported; this holds only for the Latin American economies. This finding is particularly significant as there have been several recent papers that incorporate this feature into theoretical models of emerging market business cycles, including Neumeyer and Perri (2005), Uribe and Yue (2005), Aguiar and Gopinath (2006) and Arellano (2008). Furthermore, real interest rates are, on average, less volatile than in the developed countries; this also contradicts the previous literature.

Seventhly, broad money is either weakly procyclical or acyclical in developing countries, whereas it is procyclical in developed economies. There is evidence that money leads the cycle in numerous developing economies. Therefore, monetary shocks are an important source of business cycle fluctuations in these countries. However, domestic credit, which is thought to fulfil an important role in determining investment, and hence economic activity, in developing economies, is found to lag, rather than lead, the cycle. This implies that fluctuations in output influence credit rather than credit influencing the business cycle.

Eighthly, output fluctuations in developing countries are positively correlated with economic activity in the main industrialised countries, as proxied by world output and world real interest rate; these findings are consistent with Agénor *et al.* (2000). Furthermore, examining the correlation between the developed and developing country pairs, there is evidence of strong synchronisation for a large proportion of the developing countries, particularly within the Latin American and Asian regions.

Ninthly, imports and exports are strongly procyclical in both developed countries and developing countries. However, there is no consistent relationship with the trade balance. The terms of trade provide an interesting distinction between the developed and the developing countries, being countercyclical for the developed countries and strongly procyclical for the majority of developing countries. This is similar to the findings of both Agénor *et al*. (2000) and Rand and Tarp (2002), although for somewhat smaller samples.

Tenthly, there is no consistent pattern of cyclicality of exchange rates amongst the developing countries. However, fluctuations in real exchange rates are persistent and volatile, which is consistent with the findings for the developed countries.

Finally, developing country business cycles are characterised by significantly persistent output fluctuations. However, the magnitude of this persistence is somewhat lower than for the developed countries. Furthermore, prices and nominal wages are significantly persistent in developing countries. This finding is important, because it justifies the use of theoretical models with staggered prices and wages for the modelling of developing country business cycles.

Further examination of the persistence of output fluctuations in developing countries revealed a significant, and previously undocumented, relationship; namely that, the magnitude of output persistence is positively related to the level of economic development.[1]

The persistence of output fluctuations in industrialised countries has been one of the central issues concerning macroeconomists in recent years. In particular, New Keynesian economists have stressed the importance of imperfect competition and nominal rigidities in generating persistent output fluctuations in response to monetary policy shocks. This body of work originates from the seminal papers of Taylor (1980) and Blanchard (1983), which examine output persistence in the context of staggered price and wage contracts. Their intuition is extended to a general equilibrium model in the influential work of Chari, Kehoe and McGrattan (2000). However, rather surprisingly, they find that a staggered price mechanism is, by itself, incapable of generating persistent output fluctuations beyond the exogenously imposed contract rigidity.

Thus, the need for an alternative specification of the sticky price model became apparent and, amongst other suggestions, a number of papers expressed the importance of input-output structures in the transmission of business cycle shocks, for example Bergin and Feenstra (2000). Furthering this intuition, Huang and Liu (2001) propose a dynamic general equilibrium model with sticky prices and a vertical input-output structure. In this model, the production of a final consumption good involves multiple stages of processing and, in order to generate real effects of a monetary shock, prices are staggered among

[1] As measured by GDP per capita and Energy use per capita.

firms within each stage. The input-output structure is fashioned through producers, at all but the initial stage, requiring inputs of labour and a composite of goods produced at earlier stages. Through the input-output relations across stages and the staggered prices within stages, the model is capable of generating persistence output fluctuations in response to monetary policy shocks as well as replicating the observed pattern of dampening price adjustment, as documented by Clark (1999). Furthermore, as production chain length increases, movements in the price level decrease, and fluctuations in aggregate output become increasingly persistence.

The observation of procyclical real wages and significant price persistence amongst the developing countries indicated the suitability of a New Keynesian dynamic general equilibrium model with sticky prices, to explore this relationship; thus, the vertical production chain model of Huang and Liu (2001) was implemented. This model lends itself to such an analysis, as by altering the number of production stages (N) it is possible to represent economies at different levels of development. For example, the world's least economically developed countries, such as Malawi, rely very heavily on exports of agriculture and raw materials, whilst having very little industrial production. These countries can be represented by a very simple input-output structure with just one or two production stages. On the other hand, an emerging market economy, such as Malaysia, will have a much more developed multi-sector economy. Accordingly, more stages can be incorporated to represent this.

The results support the key premise of Huang and Liu (2001), namely that there is a strong positive relationship between the number of production stages and the magnitude of output persistence. However, the effect of increasing the number of stages is severely limited by the share of intermediate goods in production ($\gamma$). This was particularly poignant in the modelling of the US and UK; both countries are highly economically developed and have correspondingly high N values. However, calibration gave low values of $\gamma$ which effectively inhibited the model from generating anywhere near the observed level of persistence. Nonetheless, after abstracting from the US and UK results, there was found to be a strong significant positive relationship between the magnitude of output persistence generated by the model and economic development, matching the pattern observed in the data. Thus, whilst the model struggles to match the observed persistence in the most economically developed economies, it performs remarkably well for the low to middle-income economies.

Finally, a very significant finding of this analysis is that the model overestimates output persistence in high inflation countries and underestimates output persistence in low inflation countries. This has important implications not only for this model, but also for any economist attempting to construct a business cycle model capable of replicating the observed patterns of output persistence. It may be possible to account for this inflation dichotomy by increasing the degree of price stickiness in low inflation countries, perhaps by increasing the number of price setting cohorts, and conversely by decreasing the degree of price stickiness in high inflation economies.

## 6.2. LIMITATIONS AND FUTURE RESEARCH

True to the New Keynesian literature, this thesis has considered the importance of monetary shocks in causing business cycle fluctuations. However, whilst these are important sources of fluctuations in developing economies, as revealed in Chapter 3, it is also important to address the other sources of macroeconomic fluctuation. In particular, the pattern of both countercyclical prices and inflation observed in a number of the developing economies, pointed to the importance of supply shocks in driving these cycles.[2] Therefore, it should prove insightful to examine supply shocks within the vertical production chain model, particularly a comparative study of the impact of such a shock at the first and final production stages.

In contrast, the Real Business Cycle literature considers technological change to be the major source of business cycle fluctuations. However, recent literature has refuted the importance of such shocks; for example Gali (1999) and Basu *et al.* (2006). Against this trend, a recent paper by Phaneuf and Rebei (2008) offers new evidence for the importance of technological shocks in the context of a dynamic general equilibrium model with sticky prices and a two-stage input-output structure. In particular, Phaneuf and Rebei (2008) reveal that technology shocks at the intermediate stage have a strong impact on short-run fluctuations. A similar shock, however, at the final stage does not, and furthermore that technological improvements, depending on the type of change, can have either expansionary or contractionary effects on employment. Thus, an interesting extension to the existing literature would be to examine the role of technological shocks in a vertical production chain structure, such as that of Huang and Liu (2001), and how the effect changes as economies become more economically developed and the number of production stages increases.

[2] Both prices and inflation are strongly countercyclical in Malawi, Nigeria, Mexico, South Korea and Romania.

As previously discussed, the Huang and Liu (2001) model was found to overestimate output persistence in high inflation countries and underestimates output persistence in low inflation countries. To account for this inflation dichotomy in future research, it is intended to increase the degree of price stickiness in low inflation countries by increasing the number of price setting cohorts. And conversely by decreasing the degree of price stickiness in high inflation economies, through the reduction of the number of price setting cohorts. In the context of the vertical production chain model, countries would then be ranked according to both the level of economic development, and assigned a corresponding number of production stages (N), and the level of inflation. High inflation economies should be assigned a correspondingly small number of price setting cohorts, and low inflation economies should be assigned a correspondingly large number of price setting cohorts. This should significantly improve the fit of the model to countries' observed output persistence.

An alternative to this would be to incorporate a state-dependent, rather than time-dependent, pricing rule, following Calvo (1983), whereby the price setting decision depends on the actual state of the economy. Firms discretely change their prices each time they deviate a certain amount form their optimal value. This would enable the specification of a higher probability of changing prices in high inflation economies and a concurrent lower probability in low inflation economies, such that the time between price adjustments is greatest in the low inflation economies. This is the arrangement employed in Kiley (2000).

However, whilst the vertical production chain model has had its success in modelling the observed pattern of output persistence in developing countries, it is a closed economy model and it is thus, incapable of representing a substantial number of stylised facts, in particular the volatility and persistence of real exchange rates. Thus the next step must be to extend the model into an open economy framework, keeping the input-output structure but introducing international trade at each stage. It is well documented in the literature that countries trade in goods at different stages of production, (e.g. Feenstra, 1998; Hummels *et al.*, 1999). This is particularly important in developing countries, where there is a tendency to export raw materials and then to buy back finished products, as the facilities to develop the products themselves are limited.

Such a model would be similar to existing open economy business cycle models with vertical international trade, such as Chari *et al.* (2002), Huang and Liu (2007). Except that, whilst these models feature two identical industrialised countries, this would be an asymmetric model with one industrialised country and one developing country. As shown in Chapter 5, by changing the number of input-output stages the model can represent countries at varying levels of development and subsequently the trade between them. The idea is that the developing country will have a smaller number of stages of production, hence relatively less persistence and more volatility in output and real exchange rates.

Industrialised country activity has been found to have a significant effect on developing country business cycles (see Chapter 3 and Agénor *et al.,* 2000). Thus, the proposed model can be used to address the impact of a monetary policy shock in an industrialised country on a developing country. Additionally, it can be used to assess the impact that a change in demand for imports in the developed country has on the developing country. For example, a procyclical and leading relationship is to be expected between a developing country's business cycle and the countries that are the key recipients of its exports. If the purchasing country goes into recession, its import demand will decrease and hence the developing country's exports will decline stimulating the onset of a recession.

Thus, the ensuing results should help in the understanding of the international transmission of business cycles and will have potentially important policy implications for policy makers and market participants in both the industrialised and developing countries. Furthermore, as an open economy model, this would be potentially capable of replicating the majority of the developing country stylised facts. This would include the observed patterns of output persistence and volatility, real exchange rate persistence and volatility, and co-movements in aggregate variables across countries.

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# APPENDIX A

## A.1. COUNTRY CODES

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **AG** | = | Argentina | **JP** | = | Japan | **RM** | = | Romania |
| **BB** | = | Barbados | **KO** | = | Korea, South | **SA** | = | South Africa |
| **BG** | = | Bangladesh | **LT** | = | Lithuania | **SG** | = | Senegal |
| **BR** | = | Brazil | **MC** | = | Morocco | **SJ** | = | Slovenia |
| **CB** | = | Columbia | **MI** | = | Malawi | **SX** | = | Slovak Republic |
| **CL** | = | Chile | **MK** | = | Macedonia | **TK** | = | Turkey |
| **HK** | = | Hong Kong | **MX** | = | Mexico | **TT** | = | Trinidad and Tobago |
| **HN** | = | Hungary | **MY** | = | Malaysia | **TU** | = | Tunisia |
| **IN** | = | India | **NG** | = | Nigeria | **UG** | = | Uruguay |
| **IS** | = | Israel | **PE** | = | Peru | **UK** | = | United Kingdom |
| **IV** | = | Cote d'Ivoire | **PH** | = | Philippines | **US** | = | United States |
| **JO** | = | Jordan | **PK** | = | Pakistan | | | |

## A.2. DATA

**Table A.1** **Variable Name Codes and IMF IFS Series Codes**

| VARIABLE | CODE | IMF IFS SERIES |
|---|---|---|
| | | |
| PRODUCTION: | | |
| MANUFACTURING | MP | 66EY |
| INDUSTRIAL | IP | 66 |
| NOMINAL OUTPUT (Proxy) | NO | 66*64 |
| CPI | CPI | 64 |
| INFLATION | CCPI | 64...X |
| WAGE | W | 65 |
| RESERVE MONEY | RES | 14 |
| M1 | M1 | 34 |
| QUASI-MONEY | QUASI | 35 |
| BROAD-MONEY | BM | 34+35 |
| (Velocity Indicator) | BMVI | 34+35(index)/NO |
| DOMESTIC CREDIT | DC | 32D |
| REAL DOMESTIC CREDIT | RDC | 32D/64 |
| GOVERNMENT EXPENDITURE | GEX | 82 |
| GOVERNMENT REVENUE | GREV | 81 |
| FISCAL IMPULSE | FI | 82/81 |
| EXPORTS | EXP | 70 |
| IMPORTS | IMP | 71 |
| TRADE BALANCE | TR | 70/71 |
| EXPORT UNIT VALUE | EXPU | 74 |
| IMPORT UNIT VALUE | IMPU | 75 |
| TERMS OF TRADE | TOT | 74/75 |
| PRIVATE CONSUMPTION | PC | 96F |
| REAL CONSUMPTION | RPC | 96F/64 |
| GROSS FIXED CAPITAL FORMATION | GFCF | 93E |
| REAL INVESTMENT | RGFCF | 93E/64 |
| MONEY MARKET RATE | MMR | 60B |
| REAL MONEY MARKET RATE | RMMR | 60B/64 |
| LENDING RATE | LR | 60P |
| REAL LENDING RATE | RLR | 60P/64 |
| NOMINAL EFFECTIVE EXCHANGE RATE | NEER | ..NECE |
| REAL EFFECTIVE EXCHANGE RATE | REER | ..RECE |
| REAL WORLD OUTPUT | WO | 66(110) |
| REAL WORLD INTEREST RATE | WIR | 60D(112)/64(110) |

# APPENDIX B

## B.1. CROSS-CORRELATIONS WITH LEADS AND LAGS

**Table B.1**
**Correlation between Real Domestic Output and World Real Output and World Real Interest Rate**

| | World Output | | | | | World Real Interest Rate | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | lag 8 | lag 4 | no lag | lead 4 | lead 8 | lag 8 | lag 4 | no lag | lead 4 | lead 8 |
| US | -0.508 | -0.150 | 0.778 | 0.479 | -0.214 | -0.243 | 0.168 | 0.554 | 0.315 | -0.011 |
| UK | -0.507 | -0.133 | 0.605 | 0.385 | -0.045 | -0.385 | 0.209 | 0.440 | 0.221 | -0.047 |
| Japan | -0.353 | -0.109 | 0.815 | 0.370 | -0.438 | -0.006 | 0.281 | 0.351 | 0.058 | -0.029 |
| **Africa** | | | | | | | | | | |
| Côte d'Ivoire | 0.031 | 0.023 | 0.009 | 0.153 | 0.141 | -0.132 | 0.046 | 0.235 | 0.187 | 0.066 |
| Malawi | -0.053 | 0.144 | 0.127 | 0.050 | -0.197 | 0.149 | -0.015 | -0.015 | -0.012 | -0.110 |
| Nigeria | 0.205 | 0.140 | 0.298 | 0.042 | -0.137 | 0.078 | 0.372 | 0.113 | -0.440 | -0.661 |
| South Africa | 0.154 | 0.150 | 0.170 | -0.126 | -0.271 | 0.424 | 0.177 | 0.182 | -0.159 | -0.173 |
| Senegal | 0.547 | 0.716 | 0.502 | -0.113 | -0.435 | -0.270 | 0.734 | -0.403 | -0.699 | -0.275 |
| **North Africa** | | | | | | | | | | |
| Israel | -0.069 | -0.104 | 0.043 | 0.145 | -0.007 | -0.137 | 0.008 | 0.238 | 0.153 | 0.017 |
| Jordan | 0.023 | 0.240 | -0.035 | -0.552 | 0.278 | -0.020 | 0.203 | 0.729 | -0.483 | -0.147 |
| Morocco | -0.040 | -0.011 | 0.195 | 0.187 | -0.086 | -0.007 | 0.075 | 0.083 | -0.004 | -0.115 |
| Tunisia | -0.041 | 0.494 | 0.341 | 0.009 | -0.094 | 0.228 | 0.411 | 0.181 | 0.046 | -0.099 |
| **Latin America** | | | | | | | | | | |
| Argentina | -0.067 | -0.456 | 0.614 | 0.510 | 0.083 | -0.064 | -0.014 | 0.200 | 0.639 | 0.622 |
| Barbados | -0.130 | 0.202 | 0.447 | 0.239 | 0.081 | 0.035 | 0.250 | 0.278 | 0.236 | -0.038 |
| Brazil | -0.145 | 0.024 | 0.557 | -0.563 | -0.465 | 0.692 | 0.260 | -0.070 | -0.377 | -0.305 |
| Columbia | -0.171 | -0.062 | 0.279 | -0.092 | 0.126 | -0.170 | -0.166 | 0.037 | 0.145 | 0.201 |
| Chile | -0.289 | 0.077 | 0.602 | 0.208 | -0.143 | -0.083 | 0.110 | 0.308 | 0.173 | 0.055 |
| Mexico | 0.242 | 0.406 | 0.329 | -0.154 | -0.520 | 0.300 | 0.216 | 0.131 | -0.003 | -0.193 |
| Peru | -0.369 | -0.539 | 0.258 | 0.158 | -0.255 | -0.170 | -0.161 | 0.130 | 0.127 | 0.058 |
| Trinidad | 0.075 | 0.033 | 0.171 | -0.134 | 0.044 | -0.137 | -0.006 | 0.109 | -0.093 | 0.114 |
| Uruguay | 0.265 | 0.238 | 0.334 | 0.050 | -0.112 | 0.253 | 0.042 | 0.248 | 0.187 | 0.094 |
| **Asia** | | | | | | | | | | |
| Bangladesh | -0.318 | -0.225 | 0.071 | -0.102 | -0.033 | -0.269 | -0.025 | -0.166 | 0.014 | 0.128 |
| Hong Kong | -0.074 | -0.285 | 0.224 | 0.150 | 0.090 | 0.190 | -0.019 | 0.350 | 0.084 | -0.125 |
| India | -0.161 | 0.183 | 0.540 | 0.324 | 0.048 | 0.064 | 0.441 | 0.467 | -0.021 | -0.265 |
| Korea, South | -0.197 | -0.252 | 0.214 | 0.341 | -0.040 | -0.161 | 0.038 | 0.237 | -0.004 | -0.053 |
| Malaysia | -0.283 | -0.178 | 0.429 | 0.258 | -0.072 | -0.002 | 0.238 | 0.182 | 0.037 | 0.044 |
| Philippines | -0.186 | -0.225 | 0.093 | 0.025 | -0.253 | 0.086 | 0.055 | -0.236 | -0.184 | 0.055 |
| Pakistan | -0.179 | 0.287 | 0.152 | -0.199 | -0.229 | -0.115 | 0.192 | -0.016 | -0.042 | 0.037 |
| Turkey | -0.052 | 0.068 | 0.164 | 0.075 | 0.042 | -0.102 | 0.099 | -0.097 | 0.178 | 0.501 |
| **East Europe** | | | | | | | | | | |
| Hungary | -0.327 | -0.138 | 0.352 | 0.413 | 0.264 | 0.022 | 0.322 | 0.476 | 0.332 | -0.107 |
| Lithuania | -0.051 | 0.207 | 0.195 | -0.269 | 0.214 | -0.101 | -0.144 | 0.229 | 0.192 | -0.195 |
| Macedonia | 0.297 | -0.089 | 0.115 | 0.144 | -0.122 | 0.045 | 0.236 | -0.196 | -0.058 | 0.308 |
| Romania | -0.322 | -0.013 | 0.230 | 0.291 | 0.221 | 0.165 | 0.247 | 0.138 | 0.050 | -0.028 |
| Slovenia | -0.217 | -0.048 | 0.361 | -0.253 | -0.389 | 0.206 | -0.135 | 0.124 | -0.064 | -0.338 |
| Slovak Republic | -0.274 | -0.104 | 0.114 | -0.492 | 0.180 | -0.027 | -0.134 | -0.136 | -0.298 | 0.018 |

**Table B.2**

**Correlation between Real Domestic Output and Prices, Inflation and Real Wages**

| | CPI | | | | | Inflation | | | | | Real Wage | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | lag 8 | lag 4 | no lag | lead 4 | lead 8 | lag 8 | lag 4 | no lag | lead 4 | lead 8 | lag 8 | lag 4 | no lag | lead 4 | lead 8 |
| US | -0.172 | -0.714 | -0.465 | 0.238 | 0.556 | -0.509 | -0.477 | 0.270 | 0.573 | 0.185 | ... | ... | ... | ... | ... |
| UK | 0.111 | -0.459 | -0.514 | -0.049 | 0.441 | -0.221 | -0.392 | 0.230 | 0.302 | 0.227 | ... | ... | ... | ... | ... |
| Japan | 0.018 | -0.642 | -0.351 | 0.217 | 0.108 | -0.341 | -0.328 | 0.430 | 0.191 | -0.163 | ... | ... | ... | ... | ... |
| **Africa** | | | | | | | | | | | | | | | |
| Côte d'Ivoire | 0.006 | 0.012 | 0.165 | 0.262 | 0.111 | -0.019 | -0.002 | 0.082 | 0.130 | -0.174 | ... | ... | ... | ... | ... |
| Malawi | 0.279 | 0.327 | -0.235 | -0.388 | -0.264 | 0.135 | -0.065 | -0.409 | -0.070 | 0.147 | ... | ... | ... | ... | ... |
| Nigeria | 0.165 | 0.053 | -0.256 | -0.227 | -0.098 | -0.123 | -0.030 | -0.216 | 0.046 | 0.149 | ... | ... | ... | ... | ... |
| South Africa | -0.033 | -0.196 | -0.120 | 0.200 | 0.151 | -0.048 | -0.087 | 0.117 | 0.169 | -0.096 | ... | ... | ... | ... | ... |
| Senegal | -0.054 | 0.230 | 0.116 | -0.269 | -0.035 | -0.016 | 0.141 | 0.020 | -0.315 | 0.057 | ... | ... | ... | ... | ... |
| **North Africa** | | | | | | | | | | | | | | | |
| Israel | 0.073 | 0.267 | 0.190 | 0.174 | -0.015 | 0.443 | 0.211 | -0.426 | -0.102 | 0.261 | ... | ... | ... | ... | ... |
| Jordan | 0.033 | 0.016 | -0.158 | -0.234 | 0.017 | -0.047 | -0.050 | -0.143 | -0.046 | 0.102 | ... | ... | ... | ... | ... |
| Morocco | -0.039 | -0.070 | -0.236 | 0.031 | -0.002 | 0.031 | -0.063 | -0.074 | 0.105 | 0.071 | ... | ... | ... | ... | ... |
| Tunisia | 0.119 | 0.674 | -0.149 | -0.378 | -0.142 | 0.421 | 0.213 | -0.432 | -0.097 | 0.083 | ... | ... | ... | ... | ... |
| **Latin America** | | | | | | | | | | | | | | | |
| Argentina | -0.323 | 0.068 | 0.595 | -0.632 | -0.267 | 0.081 | 0.113 | 0.239 | -0.811 | 0.213 | ... | ... | ... | ... | ... |
| Barbados | 0.204 | -0.012 | -0.443 | -0.201 | 0.208 | -0.008 | -0.041 | -0.124 | 0.166 | 0.280 | ... | ... | ... | ... | ... |
| Brazil | -0.164 | 0.081 | 0.421 | 0.350 | 0.149 | -0.010 | -0.008 | 0.400 | 0.275 | 0.317 | ... | ... | ... | ... | ... |
| Columbia | -0.171 | -0.345 | -0.302 | 0.147 | 0.118 | -0.101 | -0.046 | 0.225 | 0.094 | -0.007 | ... | ... | ... | ... | ... |
| Chile | 0.163 | -0.138 | -0.009 | -0.025 | -0.105 | 0.028 | -0.344 | -0.130 | -0.100 | 0.442 | 0.041 | 0.371 | -0.048 | 0.303 | 0.118 |
| Mexico | 0.011 | -0.083 | -0.330 | -0.332 | -0.010 | 0.251 | -0.021 | -0.516 | -0.070 | 0.139 | -0.115 | -0.151 | 0.277 | 0.312 | 0.100 |
| Peru | -0.085 | -0.423 | -0.387 | -0.357 | -0.076 | -0.286 | -0.076 | -0.045 | 0.057 | 0.099 | ... | ... | ... | ... | ... |
| Trinidad | 0.082 | -0.055 | -0.217 | -0.208 | -0.087 | 0.057 | -0.110 | -0.146 | 0.016 | 0.080 | ... | ... | ... | ... | ... |
| Uruguay | 0.043 | -0.307 | -0.135 | 0.107 | -0.147 | 0.312 | 0.352 | -0.041 | -0.444 | -0.182 | ... | ... | ... | ... | ... |
| **Asia** | | | | | | | | | | | | | | | |
| Bangladesh | -0.035 | -0.090 | 0.055 | 0.061 | -0.061 | 0.006 | -0.014 | 0.117 | -0.049 | 0.060 | ... | ... | ... | ... | ... |
| Hong Kong | 0.871 | -0.696 | 0.074 | -0.176 | -0.582 | -0.446 | -0.540 | 0.275 | -0.427 | -0.113 | -0.869 | -0.621 | 0.405 | 0.751 | 0.683 |
| India | 0.048 | -0.197 | -0.398 | -0.151 | 0.160 | -0.084 | -0.157 | -0.099 | 0.265 | 0.179 | ... | ... | ... | ... | ... |
| Korea, South | 0.143 | -0.164 | -0.482 | -0.192 | 0.238 | 0.061 | -0.300 | -0.248 | 0.457 | 0.288 | ... | ... | ... | ... | ... |
| Malaysia | -0.036 | -0.186 | -0.071 | -0.007 | -0.031 | -0.103 | -0.059 | 0.150 | 0.039 | 0.042 | ... | ... | ... | ... | ... |
| Philippines | -0.120 | -0.192 | 0.047 | 0.086 | -0.080 | -0.180 | -0.079 | 0.127 | 0.060 | -0.152 | ... | ... | ... | ... | ... |
| Pakistan | -0.340 | -0.144 | 0.132 | 0.278 | 0.006 | -0.264 | 0.191 | 0.238 | 0.111 | -0.206 | ... | ... | ... | ... | ... |
| Turkey | -0.038 | -0.014 | -0.132 | -0.192 | 0.079 | 0.079 | 0.048 | -0.261 | -0.039 | 0.008 | ... | ... | ... | ... | ... |
| **East Europe** | | | | | | | | | | | | | | | |
| Hungary | -0.017 | -0.680 | -0.591 | -0.090 | 0.251 | -0.338 | -0.374 | 0.176 | 0.411 | 0.183 | 0.034 | 0.413 | 0.297 | -0.122 | -0.225 |
| Lithuania | -0.152 | -0.141 | -0.095 | -0.032 | 0.041 | 0.121 | 0.019 | 0.028 | -0.310 | -0.233 | ... | ... | ... | ... | ... |
| Macedonia | -0.157 | -0.341 | -0.253 | 0.031 | 0.330 | 0.138 | -0.109 | 0.455 | 0.192 | 0.150 | -0.276 | 0.579 | 0.244 | -0.230 | -0.394 |
| Romania | 0.612 | -0.211 | -0.617 | -0.352 | 0.143 | -0.137 | -0.600 | -0.278 | 0.243 | 0.345 | -0.311 | 0.486 | 0.557 | 0.182 | -0.134 |
| Slovenia | 0.077 | 0.097 | 0.579 | 0.337 | 0.061 | 0.082 | -0.309 | 0.557 | -0.340 | -0.209 | -0.245 | -0.487 | 0.336 | 0.186 | 0.323 |
| Slovak Republic | 0.153 | 0.558 | 0.130 | -0.476 | -0.307 | 0.270 | -0.039 | -0.460 | -0.406 | 0.099 | -0.513 | -0.450 | 0.000 | 0.539 | 0.430 |

**Table B.3**

**Correlation between Real Domestic Output and Consumption and Investment**

| | Real Private Consumption | | | | | Real Gross Fixed Capital Formation | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | lag 8 | lag 4 | no lag | lead 4 | lead 8 | lag 8 | lag 4 | no lag | lead 4 | lead 8 |
| US | -0.113 | 0.617 | 0.675 | -0.097 | -0.493 | -0.239 | 0.383 | 0.869 | 0.146 | -0.500 |
| UK | -0.323 | 0.152 | 0.518 | 0.264 | -0.001 | -0.327 | 0.032 | 0.510 | 0.494 | 0.007 |
| Japan | -0.238 | 0.425 | 0.368 | -0.084 | -0.126 | -0.506 | 0.056 | 0.764 | 0.338 | -0.106 |
| **Africa** | | | | | | | | | | |
| Côte d'Ivoire | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Malawi | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Nigeria | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| South Africa | -0.508 | 0.039 | 0.564 | 0.332 | 0.183 | -0.619 | -0.060 | 0.631 | 0.605 | 0.108 |
| Senegal | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| **North Africa** | | | | | | | | | | |
| Israel | 0.056 | -0.065 | 0.250 | 0.100 | -0.141 | -0.010 | -0.011 | 0.374 | -0.060 | -0.398 |
| Jordan | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Morocco | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Tunisia | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| **Latin America** | | | | | | | | | | |
| Argentina | -0.359 | -0.187 | 0.707 | 0.685 | -0.407 | -0.121 | 0.206 | 0.897 | 0.474 | -0.551 |
| Barbados | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Brazil | -0.112 | -0.281 | 0.488 | -0.061 | 0.071 | -0.080 | -0.309 | 0.642 | -0.116 | -0.262 |
| Columbia | 0.000 | 0.174 | 0.643 | -0.298 | -0.203 | -0.397 | 0.013 | 0.666 | -0.211 | -0.074 |
| Chile | 0.781 | -0.271 | 0.224 | -0.574 | 0.876 | 0.152 | 0.853 | -0.954 | 0.142 | 0.720 |
| Mexico | -0.246 | -0.230 | 0.563 | 0.290 | 0.081 | -0.324 | -0.109 | 0.802 | 0.218 | -0.067 |
| Peru | ... | ... | ... | ... | ... | -0.152 | 0.166 | 0.771 | 0.355 | -0.066 |
| Trinidad | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Uruguay | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| **Asia** | | | | | | | | | | |
| Bangladesh | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Hong Kong | -0.379 | 0.118 | 0.625 | -0.002 | -0.412 | -0.253 | -0.032 | 0.622 | 0.123 | -0.239 |
| India | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Korea, South | -0.372 | -0.280 | 0.322 | 0.414 | 0.179 | -0.445 | -0.163 | 0.469 | 0.434 | 0.035 |
| Malaysia | 0.030 | -0.168 | -0.316 | 0.025 | 0.065 | -0.147 | -0.629 | -0.064 | 0.321 | 0.311 |
| Philippines | -0.071 | 0.100 | 0.016 | -0.014 | 0.181 | -0.158 | 0.099 | 0.203 | 0.007 | -0.057 |
| Pakistan | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Turkey | 0.122 | -0.111 | 0.665 | -0.008 | -0.072 | 0.072 | -0.235 | 0.789 | 0.095 | -0.074 |
| **East Europe** | | | | | | | | | | |
| Hungary | -0.176 | 0.322 | -0.301 | -0.379 | 0.554 | 0.366 | 0.199 | 0.008 | -0.089 | -0.075 |
| Lithuania | 0.285 | 0.079 | 0.287 | -0.177 | -0.441 | ... | ... | ... | ... | ... |
| Macedonia | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Romania | -0.534 | -0.587 | -0.105 | 0.102 | 0.225 | -0.640 | 0.294 | 0.845 | 0.634 | 0.051 |
| Slovenia | 0.460 | 0.260 | -0.587 | -0.016 | -0.135 | 0.221 | 0.317 | -0.633 | -0.139 | -0.017 |
| Slovak Republic | 0.008 | -0.517 | -0.095 | 0.352 | 0.106 | -0.179 | -0.467 | 0.039 | 0.453 | 0.232 |

**Table B.4**

**Correlation between Real Domestic Output and Government Expenditure, Government Revenue and the Fiscal Impulse**

| | Government Expenditure | | | | | Government Revenue | | | | | Fiscal Impulse | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | lag 8 | lag 4 | no lag | lead 4 | lead 8 | lag 8 | lag 4 | no lag | lead 4 | lead 8 | lag 8 | lag 4 | no lag | lead 4 | lead 8 |
| US | 0.005 | -0.193 | -0.414 | 0.029 | 0.221 | -0.481 | -0.191 | 0.594 | 0.451 | 0.031 | 0.364 | 0.033 | -0.695 | -0.332 | 0.103 |
| UK | … | … | … | … | … | … | … | … | … | … | … | … | … | … | … |
| Japan | … | … | … | … | … | … | … | … | … | … | … | … | … | … | … |
| **Africa** | | | | | | | | | | | | | | | |
| Côte d'Ivoire | … | … | … | … | … | … | … | … | … | … | … | … | … | … | … |
| Malawi | -0.134 | -0.064 | 0.092 | 0.003 | 0.097 | 0.047 | -0.123 | 0.032 | -0.133 | -0.176 | -0.135 | 0.016 | 0.076 | 0.057 | 0.150 |
| Nigeria | 0.111 | -0.095 | -0.547 | 0.239 | 0.237 | 0.219 | -0.410 | 0.094 | 0.076 | -0.244 | -0.042 | 0.346 | -0.254 | 0.118 | -0.060 |
| South Africa | -0.146 | -0.115 | 0.040 | 0.149 | 0.057 | 0.012 | -0.176 | -0.431 | -0.023 | 0.164 | 0.060 | -0.165 | -0.282 | -0.136 | 0.142 |
| Senegal | … | … | … | … | … | … | … | … | … | … | … | … | … | … | … |
| **North Africa** | | | | | | | | | | | | | | | |
| Israel | … | … | … | … | … | … | … | … | … | … | … | … | … | … | … |
| Jordan | -0.070 | 0.157 | -0.159 | 0.123 | 0.032 | 0.000 | 0.373 | -0.701 | 0.416 | 0.143 | -0.150 | 0.273 | -0.280 | 0.150 | 0.091 |
| Morocco | -0.199 | 0.212 | 0.288 | -0.258 | -0.174 | -0.145 | 0.262 | 0.237 | -0.215 | -0.136 | -0.613 | 0.030 | 0.130 | -0.309 | 0.525 |
| Tunisia | … | … | … | … | … | … | … | … | … | … | … | … | … | … | … |
| **Latin America** | | | | | | | | | | | | | | | |
| Argentina | -0.457 | 0.106 | 0.737 | 0.124 | -0.392 | 0.197 | 0.269 | 0.710 | -0.174 | -0.521 | -0.379 | -0.491 | -0.386 | 0.348 | 0.348 |
| Barbados | -0.165 | 0.070 | 0.202 | 0.131 | 0.030 | -0.113 | 0.131 | 0.195 | 0.149 | -0.098 | -0.037 | -0.046 | 0.020 | -0.004 | 0.093 |
| Brazil | -0.023 | 0.301 | 0.505 | 0.065 | -0.467 | -0.036 | 0.265 | 0.525 | 0.053 | -0.468 | 0.019 | 0.228 | -0.143 | 0.056 | 0.104 |
| Columbia | -0.149 | 0.076 | 0.349 | -0.373 | 0.129 | -0.185 | -0.184 | 0.167 | -0.044 | 0.272 | 0.040 | 0.182 | 0.119 | -0.208 | -0.065 |
| Chile | … | … | … | … | … | … | … | … | … | … | … | … | … | … | … |
| Mexico | 0.300 | 0.141 | -0.113 | -0.277 | 0.052 | 0.083 | -0.221 | -0.311 | -0.087 | 0.245 | -0.125 | -0.177 | -0.093 | -0.018 | 0.119 |
| Peru | -0.089 | -0.455 | -0.234 | -0.328 | -0.441 | -0.102 | 0.322 | 0.152 | 0.205 | -0.190 | -0.096 | 0.167 | -0.097 | 0.117 | 0.248 |
| Trinidad | … | … | … | … | … | … | … | … | … | … | … | … | … | … | … |
| Uruguay | -0.323 | -0.055 | 0.357 | 0.100 | -0.153 | -0.048 | -0.364 | -0.370 | -0.043 | 0.233 | -0.025 | -0.432 | -0.213 | -0.066 | 0.257 |
| **Asia** | | | | | | | | | | | | | | | |
| Bangladesh | … | … | … | … | … | … | … | … | … | … | … | … | … | … | … |
| Hong Kong | 0.237 | -0.230 | -0.205 | 0.107 | 0.094 | 0.394 | -0.087 | -0.580 | 0.079 | 0.258 | 0.181 | 0.090 | -0.320 | 0.025 | -0.008 |
| India | … | … | … | … | … | … | … | … | … | … | … | … | … | … | … |
| Korea, South | -0.191 | -0.037 | -0.040 | 0.062 | 0.169 | -0.111 | -0.031 | -0.391 | 0.070 | 0.254 | -0.072 | 0.009 | -0.280 | -0.057 | 0.095 |
| Malaysia | -0.004 | -0.292 | -0.211 | 0.043 | 0.153 | 0.166 | -0.235 | -0.684 | 0.002 | 0.294 | 0.261 | -0.062 | -0.318 | -0.076 | 0.110 |
| Philippines | -0.122 | -0.082 | -0.025 | -0.027 | 0.045 | 0.255 | -0.053 | -0.887 | -0.096 | 0.292 | 0.051 | 0.027 | -0.198 | -0.104 | 0.022 |
| Pakistan | … | … | … | … | … | … | … | … | … | … | … | … | … | … | … |
| Turkey | … | … | … | … | … | … | … | … | … | … | … | … | … | … | … |
| **East Europe** | | | | | | | | | | | | | | | |
| Hungary | 0.207 | 0.139 | -0.633 | -0.138 | 0.529 | 0.302 | 0.211 | -0.866 | -0.248 | 0.599 | 0.479 | 0.101 | -0.607 | -0.191 | 0.446 |
| Lithuania | -0.435 | -0.959 | 0.440 | 0.747 | 0.882 | -0.480 | -0.747 | -0.899 | -0.387 | 0.436 | -0.449 | -0.805 | 0.648 | 0.174 | 0.823 |
| Macedonia | … | … | … | … | … | … | … | … | … | … | … | … | … | … | … |
| Romania | 0.661 | 0.218 | -0.022 | -0.087 | -0.146 | -0.146 | -0.171 | 0.097 | 0.298 | -0.100 | -0.291 | 0.203 | 0.435 | 0.214 | -0.552 |
| Slovenia | -0.251 | -0.258 | 0.272 | 0.459 | -0.062 | 0.131 | -0.061 | -0.641 | 0.313 | 0.095 | 0.059 | 0.042 | 0.165 | 0.004 | -0.167 |
| Slovak Republic | … | … | … | … | … | … | … | … | … | … | … | … | … | … | … |

**Table B.5**

**Correlation between Real Domestic Output and Broad Money and the Broad Money Velocity Indicator**

| | Broad Money | | | | | Broad Money Velocity Indicator | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | lag8 | lag4 | no lag | lead4 | lead8 | lag 8 | lag 4 | no lag | lead 4 | lead 8 |
| US | 0.017 | 0.392 | 0.026 | -0.230 | -0.096 | 0.478 | 0.297 | -0.690 | -0.393 | 0.116 |
| UK | -0.230 | -0.077 | 0.102 | 0.195 | 0.296 | -0.149 | -0.025 | -0.143 | 0.307 | 0.501 |
| Japan | -0.342 | 0.255 | 0.388 | -0.012 | 0.016 | 0.277 | 0.359 | -0.681 | -0.205 | 0.414 |
| **Africa** | | | | | | | | | | |
| Côte d'Ivoire | 0.329 | 0.192 | 0.196 | 0.098 | -0.192 | 0.454 | 0.129 | -0.735 | -0.065 | -0.029 |
| Malawi | -0.289 | 0.222 | 0.071 | -0.124 | 0.301 | 0.163 | -0.207 | -0.534 | 0.108 | 0.129 |
| Nigeria | 0.108 | -0.124 | -0.291 | -0.139 | 0.000 | -0.012 | -0.267 | -0.527 | 0.080 | 0.131 |
| South Africa | -0.693 | -0.177 | 0.466 | 0.575 | 0.340 | -0.347 | -0.354 | -0.540 | 0.206 | 0.541 |
| Senegal | -0.042 | 0.081 | 0.099 | -0.313 | 0.189 | 0.230 | 0.151 | -0.873 | 0.164 | 0.382 |
| **North Africa** | | | | | | | | | | |
| Israel | 0.202 | 0.080 | 0.115 | -0.126 | -0.041 | 0.121 | -0.239 | -0.493 | -0.017 | 0.206 |
| Jordan | 0.345 | -0.021 | -0.015 | -0.158 | -0.132 | 0.153 | 0.344 | -0.909 | 0.436 | 0.135 |
| Morocco | -0.149 | 0.059 | 0.098 | -0.027 | 0.057 | -0.059 | 0.263 | -0.663 | 0.151 | 0.063 |
| Tunisia | 0.054 | -0.283 | -0.173 | 0.154 | 0.237 | 0.083 | -0.177 | -0.534 | 0.639 | -0.097 |
| **Latin America** | | | | | | | | | | |
| Argentina | -0.357 | -0.020 | 0.617 | 0.258 | -0.281 | -0.371 | -0.183 | -0.794 | 0.597 | 0.364 |
| Barbados | -0.222 | 0.316 | 0.111 | -0.052 | 0.291 | 0.014 | 0.145 | -0.692 | 0.074 | 0.255 |
| Brazil | 0.046 | 0.279 | 0.388 | 0.006 | -0.329 | 0.189 | 0.235 | -0.592 | 0.409 | 0.141 |
| Columbia | -0.268 | -0.471 | 0.040 | 0.260 | 0.194 | -0.107 | -0.194 | -0.481 | 0.188 | 0.176 |
| Chile | -0.549 | -0.177 | 0.447 | 0.592 | 0.045 | 0.052 | -0.307 | -0.518 | 0.604 | 0.424 |
| Mexico | 0.023 | 0.093 | -0.029 | -0.063 | 0.096 | -0.075 | 0.056 | 0.015 | 0.134 | 0.133 |
| Peru | -0.078 | -0.338 | -0.420 | -0.476 | -0.019 | -0.006 | 0.184 | -0.678 | -0.211 | 0.475 |
| Trinidad | 0.106 | -0.014 | -0.177 | -0.343 | -0.067 | 0.069 | 0.129 | -0.833 | 0.025 | 0.026 |
| Uruguay | -0.274 | 0.182 | 0.332 | 0.136 | -0.021 | -0.090 | -0.269 | -0.398 | -0.073 | 0.480 |
| **Asia** | | | | | | | | | | |
| Bangladesh | -0.070 | 0.044 | 0.201 | -0.160 | -0.214 | 0.198 | 0.398 | -0.588 | 0.093 | -0.294 |
| Hong Kong | 0.013 | 0.521 | 0.732 | -0.185 | -0.885 | 0.139 | 0.711 | -0.606 | -0.431 | 0.466 |
| India | -0.070 | -0.063 | -0.018 | 0.031 | 0.214 | 0.019 | -0.029 | -0.162 | 0.024 | 0.200 |
| Korea, South | -0.063 | 0.397 | 0.430 | 0.094 | -0.189 | 0.004 | 0.094 | -0.442 | 0.061 | 0.066 |
| Malaysia | -0.162 | -0.127 | 0.038 | -0.049 | -0.207 | 0.282 | -0.039 | -0.906 | -0.050 | 0.254 |
| Philippines | -0.256 | 0.017 | 0.167 | 0.087 | 0.004 | 0.268 | -0.024 | -0.926 | -0.072 | 0.307 |
| Pakistan | 0.189 | 0.270 | -0.081 | -0.211 | -0.009 | 0.374 | 0.219 | -0.570 | -0.214 | 0.064 |
| Turkey | -0.100 | 0.156 | -0.372 | 0.097 | 0.273 | -0.250 | 0.165 | -0.776 | 0.210 | 0.213 |
| **East Europe** | | | | | | | | | | |
| Hungary | 0.679 | 0.120 | -0.565 | -0.711 | 0.128 | 0.473 | 0.013 | -0.838 | -0.637 | 0.104 |
| Lithuania | -0.335 | -0.418 | 0.407 | -0.316 | -0.235 | 0.013 | 0.217 | -0.935 | 0.331 | 0.426 |
| Macedonia | -0.289 | 0.222 | 0.071 | -0.124 | 0.301 | -0.232 | 0.561 | -0.354 | 0.006 | 0.191 |
| Romania | 0.536 | 0.379 | 0.065 | -0.263 | -0.504 | 0.255 | -0.573 | -0.855 | -0.070 | 0.683 |
| Slovenia | 0.158 | 0.076 | 0.304 | 0.482 | 0.033 | 0.074 | 0.093 | -0.561 | 0.626 | 0.150 |
| Slovak Republic | -0.057 | 0.212 | 0.383 | 0.153 | -0.237 | 0.061 | -0.109 | -0.594 | 0.465 | 0.130 |

**Table B.6**

**Correlation between Real Domestic Output and Credit**

| | Real Domestic Credit | | | | | Nominal Domestic Credit | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **lag 8** | **lag 4** | **no lag** | **lead 4** | **lead 8** | **lag 8** | **lag 4** | **no lag** | **lead 4** | **lead 8** |
| US | -0.342 | 0.184 | 0.771 | 0.482 | -0.213 | -0.476 | -0.164 | 0.655 | 0.670 | 0.044 |
| UK | -0.314 | -0.030 | 0.234 | 0.152 | 0.093 | -0.245 | -0.134 | 0.063 | 0.112 | 0.210 |
| Japan | -0.255 | 0.529 | 0.362 | -0.121 | -0.024 | -0.365 | 0.120 | 0.180 | 0.052 | 0.071 |
| **Africa** | | | | | | | | | | |
| Côte d'Ivoire | 0.084 | 0.065 | -0.136 | 0.065 | 0.000 | 0.105 | 0.074 | 0.009 | 0.248 | 0.094 |
| Malawi | -0.139 | -0.108 | 0.245 | 0.335 | 0.143 | 0.017 | -0.002 | 0.059 | 0.209 | 0.034 |
| Nigeria | -0.122 | -0.028 | 0.109 | 0.086 | 0.036 | -0.081 | 0.126 | -0.056 | -0.186 | -0.037 |
| South Africa | -0.658 | -0.275 | 0.394 | 0.391 | 0.167 | 0.199 | 0.069 | -0.200 | -0.028 | 0.055 |
| Senegal | 0.179 | -0.080 | -0.177 | 0.132 | 0.062 | -0.664 | -0.350 | 0.367 | 0.471 | 0.225 |
| **North Africa** | | | | | | | | | | |
| Israel | -0.049 | -0.349 | 0.042 | 0.282 | 0.243 | -0.018 | 0.227 | 0.219 | 0.161 | 0.038 |
| Jordan | -0.098 | 0.127 | -0.061 | 0.215 | 0.091 | 0.209 | 0.238 | -0.200 | -0.032 | 0.065 |
| Morocco | 0.054 | 0.054 | -0.057 | -0.055 | 0.014 | 0.043 | 0.024 | -0.134 | -0.044 | 0.011 |
| Tunisia | -0.359 | -0.230 | 0.298 | -0.119 | 0.228 | -0.041 | -0.280 | -0.194 | -0.149 | 0.064 |
| **Latin America** | | | | | | | | | | |
| Argentina | -0.604 | -0.725 | 0.177 | 0.868 | 0.433 | -0.347 | -0.250 | 0.208 | 0.473 | 0.302 |
| Barbados | -0.317 | -0.106 | 0.354 | 0.370 | -0.078 | -0.255 | -0.182 | 0.225 | 0.318 | -0.002 |
| Brazil | 0.089 | 0.095 | 0.281 | 0.532 | -0.448 | 0.025 | 0.333 | 0.476 | 0.066 | -0.456 |
| Columbia | -0.189 | -0.339 | 0.094 | 0.321 | 0.146 | -0.262 | -0.471 | -0.017 | 0.378 | 0.205 |
| Chile | -0.169 | -0.476 | -0.143 | 0.353 | 0.118 | -0.495 | -0.422 | 0.112 | 0.398 | 0.115 |
| Mexico | -0.298 | -0.015 | 0.471 | 0.367 | -0.149 | -0.223 | -0.072 | 0.217 | 0.270 | -0.077 |
| Peru | 0.077 | 0.264 | 0.174 | 0.284 | 0.523 | -0.088 | -0.435 | -0.418 | -0.368 | 0.009 |
| Trinidad | 0.063 | 0.061 | 0.019 | -0.096 | -0.065 | 0.135 | 0.061 | -0.086 | -0.218 | -0.091 |
| Uruguay | 0.005 | -0.191 | -0.196 | 0.065 | 0.422 | -0.181 | 0.243 | 0.036 | 0.102 | 0.201 |
| **Asia** | | | | | | | | | | |
| Bangladesh | 0.292 | -0.151 | 0.333 | 0.172 | 0.101 | -0.101 | -0.259 | 0.024 | 0.061 | 0.048 |
| Hong Kong | -0.499 | -0.772 | 0.289 | 0.699 | -0.463 | -0.340 | -0.568 | 0.330 | 0.362 | -0.234 |
| India | -0.026 | 0.171 | 0.437 | 0.112 | -0.223 | 0.026 | 0.176 | 0.225 | -0.075 | -0.206 |
| Korea, South | -0.351 | -0.320 | 0.187 | 0.268 | 0.049 | -0.073 | -0.064 | -0.025 | 0.178 | 0.183 |
| Malaysia | -0.261 | -0.496 | -0.108 | 0.226 | 0.431 | -0.232 | -0.521 | -0.124 | 0.206 | 0.336 |
| Philippines | -0.364 | -0.087 | 0.259 | 0.385 | 0.181 | -0.016 | 0.102 | 0.057 | -0.052 | -0.120 |
| Pakistan | 0.218 | 0.189 | 0.000 | -0.151 | -0.142 | -0.467 | -0.205 | 0.299 | 0.375 | 0.129 |
| Turkey | -0.224 | -0.126 | 0.651 | 0.400 | -0.123 | -0.175 | -0.086 | 0.538 | 0.411 | -0.022 |
| **East Europe** | | | | | | | | | | |
| Hungary | -0.614 | -0.132 | 0.415 | 0.050 | 0.006 | -0.496 | -0.404 | 0.293 | 0.216 | 0.237 |
| Lithuania | -0.354 | -0.300 | 0.239 | 0.228 | -0.075 | -0.259 | -0.354 | 0.135 | 0.183 | -0.095 |
| Macedonia | -0.173 | -0.227 | 0.207 | 0.026 | -0.137 | -0.061 | -0.357 | 0.111 | 0.038 | -0.010 |
| Romania | 0.007 | -0.705 | -0.422 | 0.834 | 0.863 | 0.280 | -0.732 | -0.434 | 0.851 | 0.563 |
| Slovenia | 0.157 | 0.141 | -0.272 | 0.112 | -0.134 | -0.146 | -0.354 | -0.480 | -0.176 | 0.521 |
| Slovak Republic | -0.155 | -0.404 | -0.460 | -0.082 | 0.549 | 0.322 | 0.198 | 0.031 | 0.236 | -0.165 |

**Table B.7**

**Correlation between Real Domestic Output and the Real Interest Rate**

| | Real Money Market Rate | | | | | Real Lending Rate | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | lag 8 | lag 4 | no lag | lead 4 | lead 8 | lag 8 | lag 4 | no lag | lead 4 | lead 8 |
| US | -0.410 | -0.188 | 0.583 | 0.543 | 0.069 | -0.440 | -0.300 | 0.577 | 0.555 | -0.002 |
| UK | -0.500 | -0.376 | 0.123 | 0.551 | 0.482 | -0.461 | -0.462 | 0.206 | 0.555 | 0.419 |
| Japan | -0.032 | -0.464 | 0.310 | 0.318 | 0.003 | -0.525 | -0.322 | 0.237 | 0.348 | 0.296 |
| **Africa** | | | | | | | | | | |
| Côte d'Ivoire | 0.134 | -0.049 | 0.099 | -0.064 | -0.069 | -0.038 | -0.136 | 0.226 | -0.076 | -0.131 |
| Malawi | ... | ... | ... | ... | ... | 0.061 | -0.099 | -0.260 | -0.153 | 0.242 |
| Nigeria | ... | ... | ... | ... | ... | -0.124 | 0.033 | 0.375 | 0.277 | 0.263 |
| South Africa | -0.529 | -0.551 | 0.153 | 0.513 | 0.346 | -0.560 | -0.561 | 0.132 | 0.497 | 0.290 |
| Senegal | 0.503 | 0.479 | 0.573 | 0.350 | 0.441 | -0.592 | 0.557 | 0.448 | -0.483 | -0.167 |
| **North Africa** | | | | | | | | | | |
| Israel | ... | ... | ... | ... | ... | 0.214 | -0.133 | -0.024 | -0.221 | -0.178 |
| Jordan | 0.331 | -0.343 | 0.172 | 0.144 | -0.465 | 0.058 | 0.127 | 0.350 | -0.330 | 0.009 |
| Morocco | -0.163 | -0.178 | 0.178 | -0.138 | 0.008 | 0.073 | 0.133 | 0.034 | 0.276 | 0.071 |
| Tunisia | -0.271 | 0.226 | 0.430 | -0.423 | 0.113 | ... | ... | ... | ... | ... |
| **Latin America** | | | | | | | | | | |
| Argentina | ... | ... | ... | ... | ... | 0.368 | -0.208 | -0.802 | -0.332 | 0.439 |
| Barbados | ... | ... | ... | ... | ... | -0.261 | -0.198 | 0.201 | 0.424 | 0.142 |
| Brazil | 0.798 | -0.166 | -0.760 | 0.034 | 0.300 | 0.609 | -0.282 | -0.739 | 0.346 | 0.734 |
| Columbia | 0.156 | -0.399 | 0.300 | 0.325 | -0.325 | 0.273 | -0.380 | 0.274 | 0.445 | -0.515 |
| Chile | 0.313 | -0.311 | -0.316 | 0.331 | -0.079 | 0.035 | -0.588 | -0.218 | -0.073 | -0.139 |
| Mexico | 0.248 | -0.037 | -0.467 | 0.095 | 0.083 | 0.238 | 0.004 | -0.475 | 0.144 | 0.165 |
| Peru | ... | ... | ... | ... | ... | -0.621 | -0.246 | -0.337 | -0.076 | 0.356 |
| Trinidad | ... | ... | ... | ... | ... | 0.180 | -0.158 | -0.069 | -0.012 | 0.195 |
| Uruguay | -0.167 | -0.159 | 0.313 | -0.172 | -0.252 | 0.521 | -0.007 | -0.362 | -0.218 | -0.119 |
| **Asia** | | | | | | | | | | |
| Bangladesh | ... | ... | ... | ... | ... | 0.272 | -0.109 | 0.060 | -0.167 | -0.031 |
| Hong Kong | -0.198 | 0.104 | 0.106 | 0.210 | 0.026 | -0.114 | 0.297 | 0.328 | -0.523 | -0.362 |
| India | -0.517 | -0.163 | 0.416 | 0.174 | -0.140 | -0.349 | -0.468 | 0.042 | 0.434 | 0.218 |
| Korea, South | 0.068 | -0.431 | -0.296 | 0.399 | 0.248 | 0.264 | -0.295 | -0.357 | 0.337 | 0.259 |
| Malaysia | -0.430 | -0.118 | 0.805 | 0.086 | -0.459 | -0.296 | -0.266 | 0.749 | 0.163 | -0.408 |
| Philippines | -0.208 | -0.186 | 0.231 | 0.097 | -0.145 | -0.225 | -0.257 | 0.077 | 0.338 | 0.007 |
| Pakistan | -0.010 | -0.011 | -0.003 | 0.065 | -0.020 | ... | ... | ... | ... | ... |
| Turkey | 0.037 | -0.129 | -0.217 | 0.179 | -0.099 | ... | ... | ... | ... | ... |
| **East Europe** | | | | | | | | | | |
| Hungary | ... | ... | ... | ... | ... | -0.338 | -0.504 | -0.010 | 0.299 | -0.197 |
| Lithuania | 0.017 | -0.107 | -0.121 | 0.477 | 0.135 | 0.018 | 0.151 | -0.023 | 0.442 | 0.379 |
| Macedonia | ... | ... | ... | ... | ... | -0.092 | 0.287 | 0.089 | 0.100 | 0.403 |
| Romania | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Slovenia | 0.087 | 0.159 | -0.044 | -0.118 | -0.341 | -0.343 | -0.216 | 0.253 | -0.139 | -0.266 |
| Slovak Republic | -0.444 | 0.381 | 0.220 | 0.763 | -0.364 | -0.892 | -0.532 | 0.448 | -0.266 | 0.788 |

**Table B.8**

**Correlation between Real Domestic Output and Imports and Exports**

| | Imports | | | | | Exports | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | lag 8 | lag 4 | no lag | lead 4 | lead 8 | lag 8 | lag 4 | no lag | lead 4 | lead 8 |
| US | -0.353 | -0.223 | 0.583 | 0.356 | -0.071 | -0.498 | -0.512 | 0.247 | 0.544 | 0.295 |
| UK | -0.243 | -0.192 | 0.471 | 0.223 | -0.204 | -0.123 | -0.219 | 0.230 | 0.171 | -0.081 |
| Japan | -0.438 | -0.051 | 0.621 | 0.364 | -0.218 | -0.422 | 0.365 | 0.422 | 0.446 | 0.017 |
| **Africa** | | | | | | | | | | |
| Côte d'Ivoire | 0.397 | 0.016 | 0.091 | 0.142 | 0.323 | 0.238 | 0.026 | -0.191 | -0.013 | 0.037 |
| Malawi | -0.289 | -0.193 | 0.255 | -0.009 | -0.075 | 0.032 | 0.096 | 0.126 | 0.125 | -0.146 |
| Nigeria | 0.001 | -0.077 | -0.035 | 0.130 | 0.193 | -0.011 | -0.116 | 0.381 | 0.005 | -0.019 |
| South Africa | -0.242 | 0.353 | 0.711 | 0.201 | -0.137 | 0.087 | 0.585 | 0.322 | -0.061 | -0.277 |
| Senegal | … | … | … | … | … | … | … | … | … | … |
| **North Africa** | | | | | | | | | | |
| Israel | -0.223 | -0.002 | 0.348 | 0.072 | -0.156 | -0.255 | -0.060 | 0.138 | 0.039 | 0.053 |
| Jordan | -0.105 | 0.103 | -0.030 | -0.107 | -0.003 | -0.102 | -0.243 | 0.074 | -0.034 | 0.103 |
| Morocco | -0.068 | 0.087 | -0.056 | 0.041 | 0.002 | 0.026 | -0.093 | 0.130 | -0.055 | -0.108 |
| Tunisia | -0.343 | -0.002 | 0.077 | 0.084 | 0.202 | -0.276 | -0.106 | 0.310 | 0.105 | 0.149 |
| **Latin America** | | | | | | | | | | |
| Argentina | -0.350 | -0.222 | 0.740 | 0.605 | -0.389 | 0.554 | 0.107 | 0.390 | -0.079 | -0.504 |
| Barbados | -0.069 | 0.068 | 0.375 | 0.066 | -0.138 | 0.034 | -0.013 | 0.065 | -0.085 | 0.035 |
| Brazil | -0.091 | -0.201 | 0.581 | 0.066 | -0.105 | 0.149 | 0.025 | 0.161 | -0.025 | -0.308 |
| Columbia | -0.274 | -0.144 | 0.396 | 0.063 | 0.249 | -0.023 | 0.284 | 0.200 | -0.126 | 0.265 |
| Chile | -0.371 | 0.380 | -0.202 | 0.288 | -0.102 | 0.210 | -0.310 | 0.581 | -0.085 | -0.306 |
| Mexico | -0.307 | 0.303 | 0.766 | 0.168 | -0.242 | -0.123 | 0.329 | 0.347 | 0.063 | -0.002 |
| Peru | -0.525 | 0.015 | 0.667 | 0.218 | 0.041 | 0.113 | 0.011 | -0.042 | 0.048 | 0.195 |
| Trinidad | -0.142 | -0.464 | 0.010 | -0.092 | 0.162 | -0.115 | -0.291 | 0.024 | 0.182 | -0.296 |
| Uruguay | -0.203 | 0.218 | 0.656 | 0.246 | -0.151 | -0.358 | 0.084 | 0.500 | 0.143 | 0.143 |
| **Asia** | | | | | | | | | | |
| Bangladesh | -0.044 | -0.243 | 0.305 | -0.013 | -0.192 | -0.060 | -0.057 | -0.014 | 0.133 | -0.128 |
| Hong Kong | -0.288 | -0.067 | 0.662 | -0.019 | -0.286 | -0.230 | -0.186 | 0.638 | 0.053 | -0.339 |
| India | -0.008 | -0.255 | -0.446 | 0.057 | 0.411 | 0.066 | 0.059 | 0.063 | 0.186 | -0.093 |
| Korea, South | -0.246 | -0.087 | 0.529 | 0.197 | -0.303 | -0.142 | -0.087 | 0.345 | -0.143 | -0.289 |
| Malaysia | -0.261 | -0.406 | 0.255 | 0.144 | -0.095 | -0.388 | -0.151 | 0.547 | 0.067 | -0.312 |
| Philippines | -0.803 | -0.726 | 0.590 | -0.036 | 0.041 | 0.338 | 0.154 | 0.103 | -0.446 | -0.422 |
| Pakistan | -0.246 | -0.055 | 0.225 | 0.301 | -0.103 | -0.089 | 0.216 | 0.242 | 0.069 | -0.073 |
| Turkey | 0.083 | -0.080 | 0.641 | -0.271 | -0.144 | 0.102 | -0.016 | 0.112 | -0.040 | -0.112 |
| **East Europe** | | | | | | | | | | |
| Hungary | 0.286 | 0.002 | 0.001 | -0.101 | -0.114 | 0.034 | -0.102 | 0.117 | 0.304 | 0.317 |
| Lithuania | 0.362 | 0.131 | -0.007 | -0.419 | -0.139 | 0.042 | 0.301 | -0.068 | -0.547 | 0.016 |
| Macedonia | -0.059 | -0.016 | 0.265 | -0.429 | -0.035 | -0.043 | 0.006 | 0.433 | -0.109 | -0.180 |
| Romania | -0.068 | 0.507 | 0.640 | 0.372 | -0.129 | 0.323 | 0.679 | 0.583 | 0.083 | -0.325 |
| Slovenia | 0.398 | -0.369 | 0.088 | 0.054 | 0.001 | 0.351 | -0.609 | 0.220 | 0.177 | 0.085 |
| Slovak Republic | 0.048 | -0.313 | 0.545 | 0.181 | 0.171 | 0.023 | -0.048 | 0.502 | 0.180 | 0.313 |

**Table B.9**

**Correlation between Real Domestic Output and the Trade Balance and the Terms of Trade**

| | Trade Ratio | | | | | Terms of Trade | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | lag 8 | lag 4 | no lag | lead 4 | lead 8 | lag 8 | lag 4 | no lag | lead 4 | lead 8 |
| US | -0.247 | -0.403 | -0.309 | 0.314 | 0.448 | 0.356 | 0.386 | -0.006 | -0.370 | -0.261 |
| UK | 0.169 | 0.001 | -0.343 | -0.110 | 0.174 | 0.151 | 0.191 | -0.172 | -0.158 | 0.244 |
| Japan | 0.275 | -0.244 | -0.545 | -0.154 | 0.330 | 0.425 | 0.239 | -0.361 | -0.276 | 0.029 |
| **Africa** | | | | | | | | | | |
| Côte d'Ivoire | -0.047 | 0.049 | -0.209 | -0.107 | -0.230 | 0.083 | 0.080 | 0.193 | 0.155 | -0.197 |
| Malawi | 0.215 | 0.204 | -0.098 | 0.090 | -0.057 | 0.090 | 0.275 | 0.058 | 0.047 | -0.381 |
| Nigeria | -0.009 | -0.039 | 0.333 | -0.090 | -0.156 | ... | ... | ... | ... | ... |
| South Africa | 0.344 | 0.072 | -0.557 | -0.290 | -0.080 | -0.205 | 0.026 | 0.221 | -0.006 | 0.005 |
| Senegal | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| **North Africa** | | | | | | | | | | |
| Israel | 0.068 | -0.029 | -0.253 | -0.045 | 0.186 | -0.008 | 0.072 | 0.133 | -0.020 | -0.126 |
| Jordan | -0.034 | -0.325 | 0.086 | 0.042 | 0.102 | ... | ... | ... | ... | ... |
| Morocco | 0.091 | -0.165 | 0.210 | -0.086 | -0.123 | 0.111 | -0.145 | -0.142 | -0.007 | -0.087 |
| Tunisia | -0.055 | -0.208 | 0.321 | -0.069 | 0.049 | ... | ... | ... | ... | ... |
| **Latin America** | | | | | | | | | | |
| Argentina | 0.558 | 0.254 | -0.692 | -0.711 | 0.314 | 0.281 | -0.089 | 0.284 | -0.462 | -0.519 |
| Barbados | 0.067 | -0.058 | -0.153 | -0.123 | 0.122 | ... | ... | ... | ... | ... |
| Brazil | 0.185 | 0.233 | -0.515 | -0.077 | -0.062 | 0.175 | 0.147 | -0.315 | -0.096 | -0.179 |
| Columbia | 0.202 | 0.294 | -0.191 | -0.127 | -0.043 | -0.002 | 0.237 | 0.170 | -0.126 | 0.139 |
| Chile | 0.151 | -0.439 | 0.523 | -0.452 | -0.036 | ... | ... | ... | ... | ... |
| Mexico | 0.250 | -0.092 | -0.608 | -0.146 | 0.277 | ... | ... | ... | ... | ... |
| Peru | 0.526 | -0.009 | -0.554 | -0.163 | 0.043 | ... | ... | ... | ... | ... |
| Trinidad | 0.022 | 0.159 | 0.018 | 0.231 | -0.340 | 0.219 | 0.139 | -0.093 | -0.176 | -0.406 |
| Uruguay | -0.036 | -0.148 | -0.273 | -0.151 | 0.307 | ... | ... | ... | ... | ... |
| **Asia** | | | | | | | | | | |
| Bangladesh | -0.004 | 0.177 | -0.269 | 0.084 | 0.084 | ... | ... | ... | ... | ... |
| Hong Kong | 0.284 | -0.327 | -0.317 | 0.204 | 0.010 | 0.416 | -0.288 | -0.555 | 0.276 | 0.078 |
| India | 0.092 | 0.140 | 0.203 | 0.044 | -0.265 | -0.405 | 0.046 | 0.321 | 0.394 | -0.009 |
| Korea, South | 0.168 | 0.029 | -0.322 | -0.343 | 0.107 | -0.035 | 0.349 | 0.362 | -0.055 | -0.004 |
| Malaysia | 0.106 | 0.328 | -0.026 | -0.265 | -0.200 | -0.052 | -0.280 | 0.525 | 0.272 | -0.596 |
| Philippines | 0.764 | 0.546 | -0.152 | -0.471 | -0.472 | 0.249 | 0.672 | 0.451 | -0.759 | -0.487 |
| Pakistan | 0.111 | 0.220 | 0.032 | -0.160 | 0.027 | 0.046 | 0.248 | 0.046 | -0.166 | -0.139 |
| Turkey | -0.022 | 0.058 | -0.545 | 0.249 | 0.078 | -0.023 | 0.166 | 0.075 | 0.057 | -0.041 |
| **East Europe** | | | | | | | | | | |
| Hungary | -0.231 | -0.095 | 0.107 | 0.371 | 0.398 | -0.261 | 0.238 | 0.357 | 0.235 | -0.067 |
| Lithuania | -0.531 | 0.258 | -0.109 | -0.272 | 0.337 | 0.199 | 0.052 | 0.101 | -0.119 | -0.263 |
| Macedonia | 0.048 | 0.021 | 0.074 | 0.518 | -0.207 | ... | ... | ... | ... | ... |
| Romania | 0.469 | 0.274 | 0.013 | -0.304 | -0.265 | ... | ... | ... | ... | ... |
| Slovenia | 0.028 | -0.477 | 0.171 | 0.171 | 0.128 | ... | ... | ... | ... | ... |
| Slovak Republic | -0.011 | 0.430 | 0.080 | 0.027 | 0.069 | ... | ... | ... | ... | ... |

**Table B.10**

**Correlation between Real Domestic Output and the Exchange Rate**

| | NEER | | | | | REER | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | lag 8 | lag 4 | no lag | lead 4 | lead 8 | lag 8 | lag 4 | no lag | lead 4 | lead 8 |
| US | 0.133 | -0.186 | -0.164 | -0.051 | -0.007 | 0.039 | -0.256 | -0.144 | 0.101 | -0.211 |
| UK | -0.358 | -0.437 | -0.234 | 0.139 | 0.455 | -0.194 | -0.408 | -0.342 | 0.077 | 0.504 |
| Japan | 0.189 | -0.078 | -0.247 | -0.518 | -0.086 | 0.224 | -0.027 | -0.242 | -0.544 | -0.121 |
| **Africa** | | | | | | | | | | |
| Côte d'Ivoire | 0.088 | 0.066 | -0.062 | 0.363 | -0.087 | 0.199 | 0.065 | -0.166 | 0.240 | -0.102 |
| Malawi | -0.300 | -0.016 | 0.428 | 0.179 | 0.165 | -0.218 | 0.161 | 0.364 | -0.033 | 0.054 |
| Nigeria | -0.137 | -0.344 | -0.092 | -0.067 | -0.007 | -0.088 | -0.293 | -0.219 | -0.161 | -0.034 |
| South Africa | -0.227 | 0.107 | 0.008 | 0.051 | 0.221 | -0.203 | 0.087 | -0.021 | 0.058 | 0.263 |
| Senegal | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| **North Africa** | | | | | | | | | | |
| Israel | -0.168 | -0.334 | -0.225 | -0.141 | 0.010 | 0.005 | -0.399 | -0.115 | 0.126 | -0.026 |
| Jordan | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Morocco | 0.090 | -0.093 | -0.090 | -0.144 | 0.071 | 0.201 | -0.061 | -0.290 | -0.072 | 0.137 |
| Tunisia | -0.073 | 0.097 | -0.086 | 0.095 | 0.076 | 0.121 | 0.395 | -0.128 | -0.140 | 0.027 |
| **Latin America** | | | | | | | | | | |
| Argentina | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Barbados | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Brazil | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Columbia | -0.199 | 0.383 | 0.263 | 0.225 | -0.427 | -0.371 | 0.228 | 0.292 | 0.354 | -0.402 |
| Chile | 0.101 | -0.458 | 0.110 | -0.062 | -0.320 | -0.538 | -0.182 | 0.998 | 0.048 | -0.274 |
| Mexico | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Peru | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Trinidad | 0.328 | 0.145 | -0.129 | -0.144 | -0.226 | 0.379 | 0.093 | -0.229 | -0.142 | -0.219 |
| Uruguay | -0.404 | -0.512 | -0.274 | -0.037 | 0.081 | -0.477 | -0.413 | -0.115 | -0.085 | 0.028 |
| **Asia** | | | | | | | | | | |
| Bangladesh | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Hong Kong | -0.046 | -0.681 | 0.091 | 0.724 | -0.083 | -0.108 | -0.356 | 0.069 | 0.381 | -0.013 |
| India | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Korea, South | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Malaysia | -0.393 | 0.017 | 0.359 | 0.119 | -0.150 | -0.446 | -0.005 | 0.318 | 0.132 | -0.077 |
| Philippines | 0.005 | 0.119 | 0.277 | 0.014 | -0.039 | -0.156 | -0.038 | 0.354 | 0.067 | -0.082 |
| Pakistan | -0.085 | 0.170 | -0.008 | -0.212 | -0.210 | -0.131 | 0.196 | -0.003 | -0.194 | -0.227 |
| Turkey | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| **East Europe** | | | | | | | | | | |
| Hungary | 0.200 | 0.238 | -0.339 | -0.623 | -0.243 | 0.422 | -0.098 | -0.688 | -0.617 | -0.014 |
| Lithuania | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Macedonia | 0.094 | 0.373 | -0.153 | -0.051 | -0.237 | -0.424 | -0.192 | -0.216 | 0.139 | 0.094 |
| Romania | ... | ... | ... | ... | ... | 0.159 | 0.186 | 0.285 | 0.034 | -0.062 |
| Slovenia | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Slovak Republic | -0.241 | 0.631 | 0.018 | -0.365 | 0.456 | -0.447 | 0.383 | -0.108 | -0.200 | 0.189 |

## B.2. GRANGER CAUSALITY TEST RESULTS

**Table B. 11** **Does Money Cause Output?**

| Null Hypothesis | Lags: 4 | | | Lags: 8 | | |
|---|---|---|---|---|---|---|
| | Obs | F | P | Obs | F | P |
| AG_BM does not Granger Cause AG_MP | 37 | 2.1919 | 0.0957 | 33 | 0.7861 | 0.6219 |
| AG_MP does not Granger Cause AG_BM | | 0.7009 | 0.5979 | | 4.4014 | 0.0057 |
| BB_BM does not Granger Cause BB_IP | 124 | 1.8252 | 0.1287 | 120 | 2.0067 | 0.0528 |
| BB_IP does not Granger Cause BB_BM | | 0.1809 | 0.9479 | | 1.3773 | 0.2152 |
| BR_BM does not Granger Cause BR_IP | 53 | 2.2823 | 0.0755 | 49 | 2.6625 | 0.0231 |
| BR_IP does not Granger Cause BR_BM | | 0.1283 | 0.9714 | | 0.8401 | 0.5748 |
| BS_BM does not Granger Cause BS_IP | 118 | 0.8785 | 0.4794 | 114 | 2.2999 | 0.0266 |
| BS_IP does not Granger Cause BS_BM | | 4.3233 | 0.0028 | | 1.4198 | 0.1979 |
| CB_BM does not Granger Cause CB_MP | 97 | 4.2270 | 0.0035 | 93 | 3.1572 | 0.0039 |
| CB_MP does not Granger Cause CB_BM | | 2.4241 | 0.0540 | | 0.8855 | 0.5328 |
| CL_BM does not Granger Cause CL_MP | 102 | 3.0685 | 0.0201 | 98 | 1.7621 | 0.0968 |
| CL_MP does not Granger Cause CL_BM | | 2.2016 | 0.0748 | | 2.0232 | 0.0538 |
| HK_BM does not Granger Cause HK_MP | 29 | 0.6264 | 0.6492 | 25 | 0.3913 | 0.8970 |
| HK_MP does not Granger Cause HK_BM | | 0.6169 | 0.6555 | | 0.9053 | 0.5543 |
| HN_BM does not Granger Cause HN_IP | 66 | 1.1843 | 0.3275 | 62 | 0.7322 | 0.6625 |
| HN_IP does not Granger Cause HN_BM | | 5.3906 | 0.0009 | | 1.9762 | 0.0716 |
| IN_BM does not Granger Cause IN_IP | 154 | 0.4939 | 0.7402 | 150 | 0.2843 | 0.9702 |
| IN_IP does not Granger Cause IN_BM | | 0.0586 | 0.9936 | | 1.0634 | 0.3926 |
| IS_BM does not Granger Cause IS_IP | 139 | 0.2616 | 0.9021 | 135 | 1.5388 | 0.1511 |
| IS_IP does not Granger Cause IS_BM | | 1.0742 | 0.3720 | | 1.6890 | 0.1080 |
| IV_BM does not Granger Cause IV_IP | 140 | 1.0431 | 0.3876 | 136 | 2.6862 | 0.0095 |
| IV_IP does not Granger Cause IV_BM | | 1.1956 | 0.3158 | | 1.2504 | 0.2761 |
| JO_BM does not Granger Cause JO_IP | 128 | 0.1866 | 0.9450 | 124 | 2.0027 | 0.0529 |
| JO_IP does not Granger Cause JO_BM | | 1.4780 | 0.2132 | | 0.7696 | 0.6302 |
| KO_BM does not Granger Cause KO_IP | 154 | 3.3582 | 0.0116 | 150 | 1.8056 | 0.0813 |
| KO_IP does not Granger Cause KO_BM | | 1.3423 | 0.2571 | | 1.6352 | 0.1206 |
| LN_BM does not Granger Cause LN_IP | 44 | 2.9966 | 0.0316 | 40 | 5.1691 | 0.0009 |
| LN_IP does not Granger Cause LN_BM | | 1.1365 | 0.3554 | | 1.4042 | 0.2471 |
| MC_BM does not Granger Cause MC_MP | 149 | 1.0551 | 0.3812 | 145 | 0.8227 | 0.5840 |
| MC_MP does not Granger Cause MC_BM | | 0.7292 | 0.5735 | | 0.7331 | 0.6621 |
| MI_BM does not Granger Cause MI_IP | 134 | 1.8497 | 0.1235 | 130 | 1.0075 | 0.4345 |
| MI_IP does not Granger Cause MI_BM | | 4.7217 | 0.0014 | | 2.6592 | 0.0103 |
| MK_BM does not Granger Cause MK_IP | 41 | 0.6490 | 0.6317 | 37 | 1.3384 | 0.2816 |
| MK_IP does not Granger Cause MK_BM | | 0.5658 | 0.6892 | | 0.9670 | 0.4881 |
| MX_BM does not Granger Cause MX_IP | 155 | 0.9671 | 0.4275 | 151 | 1.4275 | 0.1905 |
| MX_IP does not Granger Cause MX_BM | | 0.2818 | 0.8894 | | 0.8111 | 0.5940 |
| MY_BM does not Granger Cause MY_IP | 136 | 0.6341 | 0.6391 | 132 | 0.8908 | 0.5267 |
| MY_IP does not Granger Cause MY_BM | | 1.1310 | 0.3449 | | 0.5456 | 0.8199 |
| NG_BM does not Granger Cause NG_IP | 132 | 1.7859 | 0.1359 | 128 | 1.7390 | 0.0971 |
| NG_IP does not Granger Cause NG_BM | | 0.7809 | 0.5397 | | 0.5033 | 0.8516 |
| PE_BM does not Granger Cause PE_IP | 61 | 2.6658 | 0.0425 | 57 | 2.7583 | 0.0159 |
| PE_IP does not Granger Cause PE_BM | | 9.8509 | 0.0000 | | 4.6841 | 0.0004 |
| PH_BM does not Granger Cause PH_MP | 92 | 0.0595 | 0.9933 | 88 | 0.4091 | 0.9118 |
| PH_MP does not Granger Cause PH_BM | | 0.5744 | 0.6820 | | 0.3104 | 0.9597 |
| PK_BM does not Granger Cause PK_MP | 133 | 1.9957 | 0.0993 | 129 | 1.2513 | 0.2764 |
| PK_MP does not Granger Cause PK_BM | | 1.2390 | 0.2979 | | 0.6772 | 0.7107 |
| RM_BM does not Granger Cause RM_IP | 97 | 3.8949 | 0.0058 | 93 | 2.7233 | 0.0108 |
| RM_IP does not Granger Cause RM_BM | | 4.5843 | 0.0021 | | 3.0519 | 0.0050 |
| SA_BM does not Granger Cause SA_MP | 132 | 3.5500 | 0.0089 | 128 | 2.7599 | 0.0081 |
| SA_MP does not Granger Cause SA_BM | | 2.1909 | 0.0739 | | 1.6522 | 0.1182 |
| SG_BM does not Granger Cause SG_IP | 69 | 0.8743 | 0.4848 | 65 | 0.9980 | 0.4499 |
| SG_IP does not Granger Cause SG_BM | | 1.3272 | 0.2703 | | 0.7432 | 0.6533 |
| SJ_BM does not Granger Cause SJ_IP | 49 | 1.8644 | 0.1356 | 45 | 1.3989 | 0.2401 |
| SJ_IP does not Granger Cause SJ_BM | | 0.3601 | 0.8355 | | 1.2533 | 0.3065 |
| SX_BM does not Granger Cause SX_IP | 45 | 1.4592 | 0.2349 | 41 | 0.9902 | 0.4679 |
| SX_IP does not Granger Cause SX_BM | | 1.7499 | 0.1605 | | 0.4219 | 0.8964 |
| TK_BM does not Granger Cause TK_IP | 72 | 0.9036 | 0.4674 | 68 | 0.6996 | 0.6903 |
| TK_IP does not Granger Cause TK_BM | | 5.2531 | 0.0010 | | 2.3070 | 0.0341 |
| TT_BM does not Granger Cause TT_IP | 100 | 0.4171 | 0.7959 | 96 | 0.4817 | 0.8657 |
| TT_IP does not Granger Cause TT_BM | | 2.6532 | 0.0380 | | 2.5398 | 0.0163 |
| TU_BM does not Granger Cause TU_IP | 108 | 2.6560 | 0.0373 | 100 | 1.6618 | 0.1201 |
| TU_IP does not Granger Cause TU_BM | | 1.7411 | 0.1470 | | 1.0680 | 0.3935 |
| UY_BM does not Granger Cause UY_MP | 91 | 1.2846 | 0.2828 | 87 | 0.8196 | 0.5879 |
| UY_MP does not Granger Cause UY_BM | | 1.4745 | 0.2175 | | 0.7040 | 0.6869 |
| JP_BM does not Granger Cause JP_IP | 155 | 3.9066 | 0.0048 | 151 | 2.2055 | 0.0307 |
| JP_IP does not Granger Cause JP_BM | | 1.6442 | 0.1663 | | 1.3841 | 0.2089 |
| UK_BM does not Granger Cause UK_IP | 155 | 1.0114 | 0.4036 | 151 | 1.0596 | 0.3953 |
| UK_IP does not Granger Cause UK_BM | | 0.6236 | 0.6464 | | 0.8640 | 0.5487 |
| US_BM does not Granger Cause US_IP | 155 | 4.1516 | 0.0032 | 151 | 1.9296 | 0.0605 |
| US_IP does not Granger Cause US_BM | | 0.7077 | 0.5879 | | 0.9723 | 0.4604 |

**Table B. 12(a)** **Does Credit Cause Output? (Real Domestic Credit)**

| Null Hypothesis | Lags: 4 | | | Lags: 8 | | |
|---|---|---|---|---|---|---|
| | Obs | F | P | Obs | F | P |
| AG_RDC does not Granger Cause AG_MP | 37 | 1.1727 | 0.3441 | 33 | 0.7980 | 0.6129 |
| AG_MP does not Granger Cause AG_RDC | | 3.8289 | 0.0132 | | 5.9729 | 0.0012 |
| BB_RDC does not Granger Cause BB_IP | 124 | 3.4717 | 0.0102 | 120 | 0.9761 | 0.4589 |
| BB_IP does not Granger Cause BB_RDC | | 1.9546 | 0.1061 | | 1.2587 | 0.2734 |
| BR_RDC does not Granger Cause BR_IP | 48 | 0.3070 | 0.8716 | 44 | 1.4607 | 0.2177 |
| BR_IP does not Granger Cause BR_RDC | | 0.9963 | 0.4212 | | 4.3665 | 0.0018 |
| BS_RDC does not Granger Cause BS_IP | 41 | 1.3018 | 0.2903 | 37 | 1.8592 | 0.1245 |
| BS_IP does not Granger Cause BS_RDC | | 2.5047 | 0.0616 | | 0.7665 | 0.6356 |
| CB_RDC does not Granger Cause CB_MP | 97 | 2.8641 | 0.0278 | 93 | 2.6339 | 0.0133 |
| CB_MP does not Granger Cause CB_RDC | | 2.3315 | 0.0620 | | 0.9268 | 0.4995 |
| CL_RDC does not Granger Cause CL_MP | 102 | 2.6193 | 0.0399 | 98 | 2.7016 | 0.0109 |
| CL_MP does not Granger Cause CL_RDC | | 2.0302 | 0.0965 | | 1.3854 | 0.2154 |
| HK_RDC does not Granger Cause HK_MP | 41 | 3.2913 | 0.0228 | 37 | 1.9455 | 0.1087 |
| HK_MP does not Granger Cause HK_RDC | | 0.1304 | 0.9702 | | 0.4897 | 0.8492 |
| HN_RDC does not Granger Cause HN_IP | 66 | 2.0716 | 0.0965 | 62 | 1.8288 | 0.0964 |
| HN_IP does not Granger Cause HN_RDC | | 0.5141 | 0.7256 | | 0.5928 | 0.7786 |
| IN_RDC does not Granger Cause IN_IP | 154 | 1.5708 | 0.1852 | 150 | 1.5600 | 0.1428 |
| IN_IP does not Granger Cause IN_RDC | | 2.2546 | 0.0661 | | 2.7494 | 0.0077 |
| IS_RDC does not Granger Cause IS_IP | 95 | 1.6683 | 0.1647 | 91 | 1.6046 | 0.1381 |
| IS_IP does not Granger Cause IS_RDC | | 1.7859 | 0.1390 | | 1.5711 | 0.1482 |
| IV_RDC does not Granger Cause IV_IP | 140 | 0.3075 | 0.8726 | 136 | 0.2742 | 0.9732 |
| IV_IP does not Granger Cause IV_RDC | | 1.6794 | 0.1585 | | 1.0368 | 0.4125 |
| JO_RDC does not Granger Cause JO_IP | 112 | 4.4628 | 0.0023 | 108 | 3.9781 | 0.0004 |
| JO_IP does not Granger Cause JO_RDC | | 13.7641 | 0.0000 | | 8.1485 | 0.0000 |
| KO_RDC does not Granger Cause KO_IP | 136 | 1.0423 | 0.3881 | 132 | 0.8627 | 0.5502 |
| KO_IP does not Granger Cause KO_RDC | | 0.8725 | 0.4825 | | 0.6887 | 0.7008 |
| LT_RDC does not Granger Cause LT_IP | 45 | 1.6244 | 0.1893 | 41 | 1.0931 | 0.4014 |
| LT_IP does not Granger Cause LT_RDC | | 0.2931 | 0.8806 | | 1.0735 | 0.4135 |
| MC_RDC does not Granger Cause MC_MP | 149 | 0.2047 | 0.9354 | 145 | 0.8914 | 0.5258 |
| MC_MP does not Granger Cause MC_RDC | | 0.3468 | 0.8459 | | 0.4115 | 0.9123 |
| MI_RDC does not Granger Cause MI_IP | 94 | 0.5014 | 0.7348 | 90 | 1.6930 | 0.1146 |
| MI_IP does not Granger Cause MI_RDC | | 2.7621 | 0.0327 | | 1.1868 | 0.3188 |
| MK_RDC does not Granger Cause MK_IP | 41 | 0.2328 | 0.9178 | 37 | 0.4281 | 0.8903 |
| MK_IP does not Granger Cause MK_RDC | | 0.9719 | 0.4365 | | 1.3709 | 0.2678 |
| MX_RDC does not Granger Cause MX_IP | 113 | 1.6358 | 0.1708 | 109 | 1.4936 | 0.1703 |
| MX_IP does not Granger Cause MX_RDC | | 2.5917 | 0.0408 | | 1.4449 | 0.1886 |
| MY_RDC does not Granger Cause MY_IP | 136 | 3.6070 | 0.0081 | 132 | 1.7051 | 0.1045 |
| MY_IP does not Granger Cause MY_RDC | | 0.3481 | 0.8450 | | 0.9868 | 0.4501 |
| NG_RDC does not Granger Cause NG_IP | 132 | 0.3944 | 0.8123 | 128 | 0.6896 | 0.7000 |
| NG_IP does not Granger Cause NG_RDC | | 0.2829 | 0.8886 | | 0.3765 | 0.9311 |
| PE_RDC does not Granger Cause PE_IP | 59 | 6.0709 | 0.0005 | 55 | 2.6011 | 0.0225 |
| PE_IP does not Granger Cause PE_RDC | | 6.9774 | 0.0002 | | 1.1384 | 0.3609 |
| PH_RDC does not Granger Cause PH_MP | 92 | 0.5952 | 0.6671 | 88 | 0.5730 | 0.7966 |
| PH_MP does not Granger Cause PH_RDC | | 0.2773 | 0.8919 | | 0.2514 | 0.9789 |
| PK_RDC does not Granger Cause PK_MP | 133 | 1.6816 | 0.1584 | 129 | 1.2129 | 0.2979 |
| PK_MP does not Granger Cause PK_RDC | | 2.9627 | 0.0223 | | 1.2409 | 0.2821 |
| RM_RDC does not Granger Cause RM_IP | 30 | 0.4113 | 0.7985 | 26 | 1.7973 | 0.2001 |
| RM_IP does not Granger Cause RM_RDC | | 2.7090 | 0.0579 | | 21.0137 | 0.0001 |
| SA_RDC does not Granger Cause SA_MP | 132 | 2.3210 | 0.0605 | 128 | 2.2046 | 0.0322 |
| SA_MP does not Granger Cause SA_RDC | | 1.2723 | 0.2845 | | 0.9675 | 0.4652 |
| SG_RDC does not Granger Cause SG_IP | 69 | 2.8512 | 0.0313 | 65 | 0.8758 | 0.5434 |
| SG_IP does not Granger Cause SG_RDC | | 2.3851 | 0.0611 | | 2.9076 | 0.0100 |
| SJ_RDC does not Granger Cause SJ_IP | 49 | 0.7213 | 0.5825 | 45 | 1.1337 | 0.3721 |
| SJ_IP does not Granger Cause SJ_RDC | | 1.8064 | 0.1466 | | 1.3684 | 0.2529 |
| SX_RDC does not Granger Cause SX_IP | 45 | 2.0129 | 0.1134 | 41 | 1.3703 | 0.2589 |
| SX_IP does not Granger Cause SX_RDC | | 0.3641 | 0.8325 | | 0.7728 | 0.6300 |
| TK_RDC does not Granger Cause TK_IP | 72 | 2.6562 | 0.0409 | 68 | 1.2435 | 0.2938 |
| TK_IP does not Granger Cause TK_RDC | | 1.6383 | 0.1757 | | 1.3754 | 0.2297 |
| TT_RDC does not Granger Cause TT_IP | 100 | 3.2870 | 0.0145 | 96 | 2.0557 | 0.0503 |
| TT_IP does not Granger Cause TT_RDC | | 1.3359 | 0.2627 | | 1.4137 | 0.2038 |
| TU_RDC does not Granger Cause TU_IP | 45 | 1.2773 | 0.2970 | 41 | 1.0062 | 0.4571 |
| TU_IP does not Granger Cause TU_RDC | | 1.3316 | 0.2770 | | 0.7972 | 0.6107 |
| UY_RDC does not Granger Cause UY_MP | 83 | 1.2132 | 0.3125 | 79 | 1.0595 | 0.4029 |
| UY_MP does not Granger Cause UY_RDC | | 0.9454 | 0.4427 | | 1.2317 | 0.2961 |
| JP_RDC does not Granger Cause JP_IP | 155 | 5.5683 | 0.0003 | 151 | 2.7293 | 0.0081 |
| JP_IP does not Granger Cause JP_RDC | | 0.4164 | 0.7966 | | 0.5385 | 0.8258 |
| UK_RDC does not Granger Cause UK_IP | 155 | 1.6511 | 0.1646 | 151 | 1.3621 | 0.2188 |
| UK_IP does not Granger Cause UK_RDC | | 0.4979 | 0.7373 | | 0.5228 | 0.8377 |
| US_RDC does not Granger Cause US_IP | 155 | 6.6815 | 0.0001 | 151 | 3.3792 | 0.0015 |
| US_IP does not Granger Cause US_RDC | | 2.9220 | 0.0232 | | 2.8620 | 0.0057 |

**Table B. 12(b)** **Does Credit Cause Output? (Nominal Domestic Credit)**

| Null Hypothesis | Lags: 4 | | | Lags: 8 | | |
|---|---|---|---|---|---|---|
| | Obs | F | P | Obs | F | P |
| AG_DC does not Granger Cause AG_MP | 37 | 0.3035 | 0.8731 | 33 | 0.7991 | 0.6121 |
| AG_MP does not Granger Cause AG_DC | | 0.8295 | 0.5178 | | 0.6133 | 0.7545 |
| BB_DC does not Granger Cause BB_IP | 124 | 3.2328 | 0.0149 | 120 | 1.5521 | 0.1486 |
| BB_IP does not Granger Cause BB_DC | | 0.9066 | 0.4626 | | 0.7188 | 0.6745 |
| BR_DC does not Granger Cause BR_IP | 53 | 3.3618 | 0.0174 | 49 | 2.6349 | 0.0243 |
| BR_IP does not Granger Cause BR_DC | | 0.2835 | 0.8871 | | 0.6132 | 0.7601 |
| BS_DC does not Granger Cause BS_IP | 118 | 1.9449 | 0.1081 | 114 | 2.2338 | 0.0312 |
| BS_IP does not Granger Cause BS_DC | | 0.6721 | 0.6127 | | 0.5992 | 0.7765 |
| CB_DC does not Granger Cause CB_MP | 97 | 3.1355 | 0.0185 | 93 | 2.6758 | 0.0120 |
| CB_MP does not Granger Cause CB_DC | | 1.8365 | 0.1289 | | 0.7383 | 0.6574 |
| CL_DC does not Granger Cause CL_MP | 102 | 2.3271 | 0.0620 | 98 | 2.5009 | 0.0176 |
| CL_MP does not Granger Cause CL_DC | | 2.2861 | 0.0659 | | 2.0422 | 0.0515 |
| HK_DC does not Granger Cause HK_MP | 41 | 2.7077 | 0.0476 | 37 | 2.0321 | 0.0949 |
| HK_MP does not Granger Cause HK_DC | | 0.0917 | 0.9844 | | 0.1693 | 0.9927 |
| HN_DC does not Granger Cause HN_IP | 66 | 2.7322 | 0.0377 | 62 | 1.3197 | 0.2585 |
| HN_IP does not Granger Cause HN_DC | | 0.5488 | 0.7006 | | 0.9269 | 0.5038 |
| IN_DC does not Granger Cause IN_IP | 154 | 0.6305 | 0.6415 | 150 | 0.7963 | 0.6068 |
| IN_IP does not Granger Cause IN_DC | | 2.8665 | 0.0253 | | 3.0677 | 0.0033 |
| IS_DC does not Granger Cause IS_IP | 136 | 2.5895 | 0.0398 | 132 | 2.3372 | 0.0230 |
| IS_IP does not Granger Cause IS_DC | | 1.7144 | 0.1508 | | 2.7985 | 0.0072 |
| IV_DC does not Granger Cause IV_IP | 140 | 0.1976 | 0.9393 | 136 | 0.3279 | 0.9539 |
| IV_IP does not Granger Cause IV_DC | | 2.6618 | 0.0355 | | 1.7771 | 0.0882 |
| JO_DC does not Granger Cause JO_IP | 128 | 12.9022 | 0.0000 | 124 | 5.9984 | 0.0000 |
| JO_IP does not Granger Cause JO_DC | | 7.5532 | 0.0000 | | 3.2757 | 0.0022 |
| KO_DC does not Granger Cause KO_IP | 154 | 0.3222 | 0.8627 | 150 | 0.5214 | 0.8388 |
| KO_IP does not Granger Cause KO_DC | | 1.6915 | 0.1551 | | 0.6170 | 0.7624 |
| LT_DC does not Granger Cause LT_IP | 45 | 0.7241 | 0.5812 | 41 | 1.1135 | 0.3891 |
| LT_IP does not Granger Cause LT_DC | | 0.6323 | 0.6427 | | 0.6405 | 0.7363 |
| MC_DC does not Granger Cause MC_MP | 149 | 0.5549 | 0.6958 | 145 | 0.8869 | 0.5296 |
| MC_MP does not Granger Cause MC_DC | | 0.1803 | 0.9483 | | 0.3072 | 0.9621 |
| MI_DC does not Granger Cause MI_IP | 134 | 0.2532 | 0.9073 | 130 | 1.1946 | 0.3086 |
| MI_IP does not Granger Cause MI_DC | | 1.3353 | 0.2606 | | 0.8893 | 0.5280 |
| MK_DC does not Granger Cause MK_IP | 41 | 0.4352 | 0.7822 | 37 | 0.8128 | 0.5999 |
| MK_IP does not Granger Cause MK_DC | | 0.7109 | 0.5905 | | 0.5169 | 0.8298 |
| MX_DC does not Granger Cause MX_IP | 155 | 3.1106 | 0.0172 | 151 | 2.0187 | 0.0487 |
| MX_IP does not Granger Cause MX_DC | | 1.1839 | 0.3204 | | 1.4209 | 0.1932 |
| MY_DC does not Granger Cause MY_IP | 136 | 4.0124 | 0.0042 | 132 | 1.7562 | 0.0929 |
| MY_IP does not Granger Cause MY_DC | | 0.1902 | 0.9431 | | 1.0658 | 0.3920 |
| NG_DC does not Granger Cause NG_IP | 132 | 0.0396 | 0.9970 | 128 | 0.1487 | 0.9965 |
| NG_IP does not Granger Cause NG_DC | | 0.4715 | 0.7566 | | 0.5472 | 0.8185 |
| PE_DC does not Granger Cause PE_IP | 61 | 7.5592 | 0.0001 | 57 | 3.5090 | 0.0037 |
| PE_IP does not Granger Cause PE_DC | | 16.3311 | 0.0000 | | 2.4440 | 0.0296 |
| PH_DC does not Granger Cause PH_MP | 92 | 1.3542 | 0.2570 | 88 | 0.8161 | 0.5908 |
| PH_MP does not Granger Cause PH_DC | | 0.4616 | 0.7637 | | 0.1375 | 0.9972 |
| PK_DC does not Granger Cause PK_MP | 133 | 0.8667 | 0.4860 | 129 | 0.6921 | 0.6978 |
| PK_MP does not Granger Cause PK_DC | | 1.6867 | 0.1572 | | 0.9096 | 0.5113 |
| RM_DC does not Granger Cause RM_IP | 30 | 0.7726 | 0.5552 | 26 | 2.6874 | 0.0812 |
| RM_IP does not Granger Cause RM_DC | | 3.3325 | 0.0291 | | 6.6317 | 0.0052 |
| SA_DC does not Granger Cause SA_MP | 132 | 2.2363 | 0.0689 | 128 | 1.9980 | 0.0531 |
| SA_MP does not Granger Cause SA_DC | | 1.8296 | 0.1274 | | 1.0249 | 0.4217 |
| SG_DC does not Granger Cause SG_IP | 69 | 2.7171 | 0.0379 | 65 | 1.1832 | 0.3288 |
| SG_IP does not Granger Cause SG_DC | | 3.5130 | 0.0121 | | 3.2098 | 0.0053 |
| SJ_DC does not Granger Cause SJ_IP | 49 | 0.6962 | 0.5991 | 45 | 1.7006 | 0.1423 |
| SJ_IP does not Granger Cause SJ_DC | | 1.9350 | 0.1234 | | 1.3526 | 0.2597 |
| SX_DC does not Granger Cause SX_IP | 45 | 1.8227 | 0.1458 | 41 | 1.3564 | 0.2648 |
| SX_IP does not Granger Cause SX_DC | | 0.2993 | 0.8765 | | 0.9289 | 0.5110 |
| TK_DC does not Granger Cause TK_IP | 72 | 2.7031 | 0.0382 | 68 | 1.5041 | 0.1791 |
| TK_IP does not Granger Cause TK_DC | | 2.4131 | 0.0582 | | 1.4044 | 0.2174 |
| TT_DC does not Granger Cause TT_IP | 100 | 3.3857 | 0.0125 | 96 | 1.6833 | 0.1155 |
| TT_IP does not Granger Cause TT_DC | | 1.8859 | 0.1196 | | 2.1078 | 0.0446 |
| TU_DC does not Granger Cause TU_IP | 109 | 1.7445 | 0.1462 | 101 | 1.5616 | 0.1488 |
| TU_IP does not Granger Cause TU_DC | | 1.8981 | 0.1166 | | 1.0491 | 0.4066 |
| UY_DC does not Granger Cause UY_MP | 91 | 1.0391 | 0.3922 | 87 | 0.7973 | 0.6068 |
| UY_MP does not Granger Cause UY_DC | | 1.0711 | 0.3762 | | 1.0621 | 0.3995 |
| JP_DC does not Granger Cause JP_IP | 155 | 1.6363 | 0.1682 | 151 | 1.9825 | 0.0532 |
| JP_IP does not Granger Cause JP_DC | | 1.2097 | 0.3092 | | 0.9662 | 0.4652 |
| UK_DC does not Granger Cause UK_IP | 155 | 0.9722 | 0.4247 | 151 | 1.0190 | 0.4248 |
| UK_IP does not Granger Cause UK_DC | | 0.3609 | 0.8361 | | 0.8623 | 0.5501 |
| US_DC does not Granger Cause US_IP | 155 | 2.3756 | 0.0547 | 151 | 1.5882 | 0.1339 |
| US_IP does not Granger Cause US_DC | | 4.3207 | 0.0025 | | 3.1956 | 0.0024 |

**Table B.13(a)** **Do Interest Rates Cause Output? (Real Lending Rate)**

| Null Hypothesis | | Lags: 4 | | | Lags: 8 | |
|---|---|---|---|---|---|---|
| | Obs | F | P. | Obs | F | P |
| AG_RLR does not Granger Cause AG_MP | 37 | 2.5503 | 0.0612 | 33 | 0.7682 | 0.6353 |
| AG_MP does not Granger Cause AG_RLR | | 1.0727 | 0.3886 | | 1.7859 | 0.1540 |
| BB_RLR does not Granger Cause BB_IP | 92 | 1.1281 | 0.3489 | 88 | 0.5418 | 0.8211 |
| BB_IP does not Granger Cause BB_RLR | | 1.9602 | 0.1082 | | 1.4952 | 0.1744 |
| BR_RLR does not Granger Cause BR_IP | 29 | 2.9483 | 0.0457 | 25 | 0.3305 | 0.9309 |
| BR_IP does not Granger Cause BR_RLR | | 2.4338 | 0.0810 | | 2.3153 | 0.1282 |
| BS_RLR does not Granger Cause BS_IP | 41 | 0.8238 | 0.5198 | 37 | 1.1363 | 0.3824 |
| BS_IP does not Granger Cause BS_RLR | | 0.0645 | 0.9920 | | 0.0266 | 1.0000 |
| CB_RLR does not Granger Cause CB_MP | 73 | 2.1617 | 0.0833 | 69 | 1.1212 | 0.3648 |
| CB_MP does not Granger Cause CB_RLR | | 2.8167 | 0.0323 | | 1.8840 | 0.0825 |
| CL_RLR does not Granger Cause CL_MP | 117 | 3.4036 | 0.0116 | 113 | 2.6644 | 0.0110 |
| CL_MP does not Granger Cause CL_RLR | | 1.4565 | 0.2205 | | 2.5780 | 0.0136 |
| HK_RLR does not Granger Cause HK_MP | 53 | 2.4805 | 0.0576 | 49 | 1.0988 | 0.3896 |
| HK_MP does not Granger Cause HK_RLR | | 0.5299 | 0.7144 | | 1.0697 | 0.4082 |
| HN_RLR does not Granger Cause HN_IP | 62 | 1.4750 | 0.2229 | 58 | 0.7464 | 0.6506 |
| HN_IP does not Granger Cause HN_RLR | | 0.9333 | 0.4518 | | 0.7533 | 0.6448 |
| IN_RLR does not Granger Cause IN_IP | 101 | 1.1012 | 0.3608 | 97 | 1.1111 | 0.3648 |
| IN_IP does not Granger Cause IN_RLR | | 1.3893 | 0.2438 | | 0.6418 | 0.7403 |
| IS_RLR does not Granger Cause IS_IP | 100 | 2.5025 | 0.0477 | 96 | 1.3338 | 0.2393 |
| IS_IP does not Granger Cause IS_RLR | | 2.1866 | 0.0767 | | 1.4537 | 0.1878 |
| JO_RLR does not Granger Cause JO_IP | 49 | 1.8919 | 0.1307 | 45 | 1.6623 | 0.1522 |
| JO_IP does not Granger Cause JO_RLR | | 0.8875 | 0.4802 | | 0.6361 | 0.7407 |
| KO_RLR does not Granger Cause KO_IP | 95 | 3.4601 | 0.0114 | 91 | 2.0991 | 0.0464 |
| KO_IP does not Granger Cause KO_RLR | | 1.5287 | 0.2010 | | 1.1020 | 0.3718 |
| LT_RLR does not Granger Cause LT_IP | 44 | 0.2455 | 0.9104 | 40 | 1.9184 | 0.1059 |
| LT_IP does not Granger Cause LT_RLR | | 2.0217 | 0.1127 | | 2.5242 | 0.0393 |
| MC_RLR does not Granger Cause MC_MP | 97 | 0.6200 | 0.6494 | 93 | 1.0390 | 0.4148 |
| MC_MP does not Granger Cause MC_RLR | | 2.7917 | 0.0310 | | 2.8541 | 0.0079 |
| MI_RLR does not Granger Cause MI_IP | 94 | 1.3636 | 0.2534 | 90 | 0.6823 | 0.7056 |
| MI_IP does not Granger Cause MI_RLR | | 1.9953 | 0.1025 | | 1.8011 | 0.0906 |
| MK_RLR does not Granger Cause MK_IP | 40 | 0.4654 | 0.7606 | 36 | 0.2930 | 0.9597 |
| MK_IP does not Granger Cause MK_RLR | | 0.7094 | 0.5917 | | 1.7901 | 0.1418 |
| MX_RLR does not Granger Cause MX_IP | 45 | 3.3696 | 0.0193 | 41 | 1.4169 | 0.2399 |
| MX_IP does not Granger Cause MX_RLR | | 1.2720 | 0.2990 | | 0.6382 | 0.7381 |
| MY_RLR does not Granger Cause MY_IP | 112 | 1.6633 | 0.1642 | 108 | 1.3939 | 0.2098 |
| MY_IP does not Granger Cause MY_RLR | | 1.0707 | 0.3749 | | 0.7222 | 0.6714 |
| NG_RLR does not Granger Cause NG_IP | 132 | 6.0214 | 0.0002 | 128 | 3.2750 | 0.0022 |
| NG_IP does not Granger Cause NG_RLR | | 0.8248 | 0.5118 | | 2.0939 | 0.0422 |
| PE_RLR does not Granger Cause PE_IP | 54 | 2.5363 | 0.0530 | 50 | 4.0388 | 0.0020 |
| PE_IP does not Granger Cause PE_RLR | | 0.8948 | 0.4750 | | 1.0248 | 0.4374 |
| PH_RLR does not Granger Cause PH_MP | 93 | 2.5444 | 0.0454 | 89 | 1.4673 | 0.1844 |
| PH_MP does not Granger Cause PH_RLR | | 2.5775 | 0.0432 | | 1.4322 | 0.1981 |
| SA_RLR does not Granger Cause SA_MP | 155 | 3.6299 | 0.0075 | 151 | 4.2528 | 0.0001 |
| SA_MP does not Granger Cause SA_RLR | | 1.8537 | 0.1217 | | 2.7803 | 0.0071 |
| SJ_RLR does not Granger Cause SJ_IP | 49 | 3.0739 | 0.0268 | 45 | 1.9369 | 0.0937 |
| SJ_IP does not Granger Cause SJ_RLR | | 0.8194 | 0.5205 | | 0.6069 | 0.7642 |
| SX_RLR does not Granger Cause SX_IP | 45 | 1.8110 | 0.1481 | 41 | 1.9402 | 0.1001 |
| SX_IP does not Granger Cause SX_RLR | | 1.3277 | 0.2784 | | 1.7012 | 0.1496 |
| TT_RLR does not Granger Cause TT_IP | 80 | 0.5110 | 0.7278 | 76 | 0.3060 | 0.9609 |
| TT_IP does not Granger Cause TT_RLR | | 2.1218 | 0.0870 | | 1.7530 | 0.1051 |
| UY_RLR does not Granger Cause UY_MP | 83 | 1.6154 | 0.1794 | 79 | 1.0618 | 0.4013 |
| UY_MP does not Granger Cause UY_RLR | | 2.1595 | 0.0819 | | 1.0463 | 0.4121 |
| JP_RLR does not Granger Cause JP_IP | 155 | 1.1276 | 0.3459 | 151 | 1.8110 | 0.0802 |
| JP_IP does not Granger Cause JP_RLR | | 2.2665 | 0.0648 | | 1.3851 | 0.2085 |
| UK_RLR does not Granger Cause UK_IP | 151 | 2.3375 | 0.0582 | 147 | 1.7144 | 0.1008 |
| UK_IP does not Granger Cause UK_RLR | | 2.0298 | 0.0934 | | 2.8466 | 0.0060 |
| US_RLR does not Granger Cause US_IP | 155 | 4.4765 | 0.0019 | 151 | 2.4205 | 0.0179 |
| US_IP does not Granger Cause US_RLR | | 11.9227 | 0.0000 | | 6.1030 | 0.0000 |

**Table B.13(b)** **Do Interest Rates Cause Output? (Real Money Market Rate)**

| Null Hypothesis | Lags: 4 | | | Lags: 8 | | |
|---|---|---|---|---|---|---|
| | Obs | F | P | Obs | F | P |
| BR_RMMR does not Granger Cause BR_IP | 47 | 3.2568 | 0.0158 | 44 | 2.3502 | 0.0462 |
| BR_IP does not Granger Cause BR_RMMR | | 0.3939 | 0.8498 | | 0.1748 | 0.9925 |
| CB_RMMR does not Granger Cause CB_MP | 36 | 1.1471 | 0.3622 | 33 | 1.3281 | 0.2985 |
| CB_MP does not Granger Cause CB_RMMR | | 3.7649 | 0.0112 | | 3.2476 | 0.0215 |
| CL_RMMR does not Granger Cause CL_MP | 108 | 3.1562 | 0.0111 | 105 | 2.0903 | 0.0450 |
| CL_MP does not Granger Cause CL_RMMR | | 0.5763 | 0.7180 | | 0.3907 | 0.9229 |
| HK_RMMR does not Granger Cause HK_MP | 40 | 1.2139 | 0.3276 | 37 | 0.9144 | 0.5247 |
| HK_MP does not Granger Cause HK_RMMR | | 2.7178 | 0.0393 | | 1.5793 | 0.1934 |
| IN_RMMR does not Granger Cause IN_IP | 126 | 0.1518 | 0.9791 | 123 | 0.4254 | 0.9035 |
| IN_IP does not Granger Cause IN_RMMR | | 3.3790 | 0.0069 | | 1.9291 | 0.0630 |
| IV_RMMR does not Granger Cause IV_IP | 109 | 1.1866 | 0.3213 | 106 | 1.9999 | 0.0554 |
| IV_IP does not Granger Cause IV_RMMR | | 0.5506 | 0.7375 | | 0.4709 | 0.8736 |
| KO_RMMR does not Granger Cause KO_IP | 109 | 4.2491 | 0.0015 | 106 | 3.1829 | 0.0032 |
| KO_IP does not Granger Cause KO_RMMR | | 2.4734 | 0.0373 | | 1.0935 | 0.3753 |
| LT_RMMR does not Granger Cause LT_IP | 40 | 0.3097 | 0.9031 | 37 | 0.2350 | 0.9793 |
| LT_IP does not Granger Cause LT_RMMR | | 1.3994 | 0.2538 | | 1.4240 | 0.2466 |
| MX_RMMR does not Granger Cause MX_IP | 91 | 3.7132 | 0.0045 | 88 | 2.6524 | 0.0132 |
| MX_IP does not Granger Cause MX_RMMR | | 0.6033 | 0.6976 | | 0.5065 | 0.8476 |
| MY_RMMR does not Granger Cause MY_IP | 135 | 4.5021 | 0.0008 | 132 | 2.2458 | 0.0289 |
| MY_IP does not Granger Cause MY_RMMR | | 1.3283 | 0.2565 | | 0.6479 | 0.7359 |
| PH_RMMR does not Granger Cause PH_MP | 92 | 1.7247 | 0.1383 | 89 | 1.2474 | 0.2847 |
| PH_MP does not Granger Cause PH_RMMR | | 0.3277 | 0.8949 | | 0.1337 | 0.9975 |
| PK_RMMR does not Granger Cause PK_MP | 132 | 1.6681 | 0.1474 | 129 | 2.4206 | 0.0189 |
| PK_MP does not Granger Cause PK_RMMR | | 1.6644 | 0.1483 | | 0.7709 | 0.6290 |
| SA_RMMR does not Granger Cause SA_MP | 154 | 3.3202 | 0.0072 | 151 | 2.9908 | 0.0041 |
| SA_MP does not Granger Cause SA_RMMR | | 2.1976 | 0.0578 | | 2.8731 | 0.0055 |
| SG_RMMR does not Granger Cause SG_IP | 68 | 4.5966 | 0.0014 | 65 | 2.9993 | 0.0082 |
| SG_IP does not Granger Cause SG_RMMR | | 0.8447 | 0.5238 | | 0.7734 | 0.6277 |
| SJ_RMMR does not Granger Cause SJ_IP | 45 | 1.5947 | 0.1881 | 42 | 0.9741 | 0.4781 |
| SJ_IP does not Granger Cause SJ_RMMR | | 0.9264 | 0.4760 | | 0.8499 | 0.5694 |
| TK_RMMR does not Granger Cause TK_IP | 70 | 8.6879 | 0.0000 | 67 | 6.2854 | 0.0000 |
| TK_IP does not Granger Cause TK_RMMR | | 0.2995 | 0.9112 | | 0.3641 | 0.9345 |
| TU_RMMR does not Granger Cause TU_IP | 44 | 0.0907 | 0.9932 | 41 | 0.9006 | 0.5316 |
| TU_IP does not Granger Cause TU_RMMR | | 1.2652 | 0.3021 | | 1.3107 | 0.2852 |
| JP_RMMR does not Granger Cause JP_IP | 154 | 4.0262 | 0.0019 | 151 | 2.8529 | 0.0058 |
| JP_IP does not Granger Cause JP_RMMR | | 2.6660 | 0.0246 | | 1.3680 | 0.2161 |
| UK_RMMR does not Granger Cause UK_IP | 128 | 3.7452 | 0.0035 | 125 | 2.6230 | 0.0115 |
| UK_IP does not Granger Cause UK_RMMR | | 6.1153 | 0.0001 | | 5.1332 | 0.0000 |
| US_RMMR does not Granger Cause US_IP | 154 | 2.0440 | 0.0760 | 151 | 1.6788 | 0.1091 |
| US_IP does not Granger Cause US_RMMR | | 5.4516 | 0.0001 | | 3.2145 | 0.0023 |

Notes: IP – real industrial production, MP – real manufacturing production, BM – broad money, DC – domestic private sector credit, RDC – real domestic private sector credit, RMMR – real money market rate, RLR – real lending rate

# APPENDIX C

This Appendix provides details of the Matlab code used to apply the Bry-Boschan (1971) algorithm; provided by kind permission of Rand and Tarp (2002).

## C.1. BRYBOS.M

```
function dating=brybos(X,F)

% function dating=brybos(X,F)
% This function applies the Bry-Boschan (1971) algorithm and determines the peaks and troughs of data
% matrix X with T time series observations and N time series. The output is a (TxN) matrix where 1 signifies a
% peak and -1 a trough. F is the frequency of the observations where monthly observations are the default.
% F=0: monthly, F=1: quarterly, F=2: annual.
% For monthly data, the minimum peak-to-trough (trough-to-peak) period is 5 months and peak-to-peak
% (trough-to-trough) is 15 months. For quarterly p-to-t is 2 quarters and p-to-p is 6 quarters. For annual
% data, p-to-t is 1 year and p-to-p is 2 years.
% The program calls on the M-functions alternate.m, check.m, dates.m, enforce.m, ma.m, mcd.m, outier.m,
% qcd.m, refine.m, spencer.m
% This program was writen by Robert Inklaar, University of Groningen (May 2003) and is an adaption of the
% programs for Gauss of Mark Watson.
% The algorithm is based on Bry and Boschan (1971), 'Cyclical analysis of time series: Selected procedures
% and computer programs', NBER: New York

if nargin == 1; F=0; end
if     F == 0; D=5;
elseif  F == 1; D=2;
elseif  F == 2; D=1;
end

N=size(X,2);
if sum(sum(isnan(X)))>0; error('Data matrix contains empty values'); end

% I - Find outliers and replace them with the Spencer curve value X=outlier(X); Moved down this step and
% only use it in step II
 % II - Peaks and troughs of one-year centered moving average (enforcing alternating peaks and troughs)

if F == 0; M=12; elseif F == 1; M=4; elseif F == 2; M=1; end
Xf=ma(outlier(X),M);
[peaks,troughs] = dates(Xf,D);
[peaks,troughs] = alternate(Xf,peaks,troughs);

if F == 0;

% III - Refine peaks and troughs with Spencer curve. Also enforce alternating peaks and troughs and a
% minimum p-to-p (t-to-t) period.

Xs=spencer(X);
[peaks,troughs] = check(peaks,troughs,D);
[peaks,troughs] = refine(Xs,peaks,troughs,D);
[peaks,troughs] = alternate(Xs,peaks,troughs);
[peaks,troughs] = enforce(Xs,peaks,troughs,D);

% IV - Refine peaks and troughs with moving average determined by the number of months/quarters of
% cyclical dominance (MCD). For annual data, the cyclical dominance is set to 1 year. Also enforce
% alternating peaks and troughs.

  if     F == 0; cdnum=mcd(X);
  elseif  F == 1; cdnum=qcd(X);
  else    cdnum=ones(1,N);
  end
```

```
   for i=1:N; Xf2(:,i)=ma(X(:,i),cdnum(i)); end
   [peaks,troughs] = check(peaks,troughs,D);
   [peaks,troughs] = refine(Xf2,peaks,troughs,D);
   [peaks,troughs] = alternate(Xf2,peaks,troughs);

% V - Refine peaks and troughs with actual series. Also enforce
% alternating peaks and troughs and a minimum p-to-p (t-to-t)period.

   span=max(4,cdnum);
   for i=1:N
      [peaks(:,i),troughs(:,i)] = check(peaks(:,i),troughs(:,i),span(i));
      [peaks(:,i),troughs(:,i)] = refine(X(:,i),peaks(:,i),troughs(:,i),span(i));
      [peaks(:,i),troughs(:,i)] = alternate(X(:,i),peaks(:,i),troughs(:,i));
      [peaks(:,i),troughs(:,i)] = enforce(X(:,i),peaks(:,i),troughs(:,i),span(i));
      [peaks(:,i),troughs(:,i)] = alternate(X(:,i),peaks(:,i),troughs(:,i));
   end
   dating=peaks-troughs;
else
   [peaks,troughs] = refine(X,peaks,troughs,D);
   [peaks,troughs] = check(peaks,troughs,D);
   [peaks,troughs] = enforce(X,peaks,troughs,D);
   [peaks,troughs] = alternate(X,peaks,troughs);
   [peaks,troughs] = enforce(X,peaks,troughs,D);
   dating=peaks-troughs;
end
```

## C.2. ALTERNATE.M

```
function [peaksalt, troughsalt] = alternate(X,peaks,troughs)

% function [peaksalt, troughsalt] = alternate(X,peaks,troughs)

% Checks if there no two subsequent peaks or troughs. If two subsequent peaks (troughs) are found, only
% the most extreme peak (trough) is retained. If the values are equal, the last peak (trough) is selected.
% This program was writen by Robert Inklaar, University of Groningen (May 2003).

[T N]=size(X);
peaksalt=peaks;
troughsalt=troughs;

for j=1:N
   Pflag=0;
   Tflag=0;
   for i=1:T
      if peaks(i,j) == 1
         if Pflag == 0
            Pflag=1;
            Tflag=0;
            pv=i;
         elseif Pflag == 1
            if X(i,j) > X(pv,j)
               peaksalt(pv,j)=0;
               pv=i;
            elseif X(i,j) < X(pv,j)
               peaksalt(i,j)=0;
            else
               peaksalt(pv,j)=0;
               pv=i;
            end
         end
```

```
      elseif troughs(i,j) == 1
        if Tflag == 0
          Tflag=1;
          Pflag=0;
          tv=i;
        elseif Tflag == 1
          if X(i,j) < X(tv,j)
            troughsalt(tv,j)=0;
            tv=i;
          elseif X(i,j) > X(tv,j)
            troughsalt(i,j)=0;
          else
            troughsalt(tv,j)=0;
            tv=i;
          end
        end
      end
    end
end
```

## C.3. CHECK.M

```
function [peaksc,troughsc]=check(peaks,troughs,D)

% function [peaksc,troughsc]=check(peaks,troughs,D)
% This functions checks whether any peaks or troughs are too close to the beginning or end of the sample. If
% this is the case, the peak/trough is moved to the first feasible point.
% This program was writen by Robert Inklaar, University of Groningen (May 2003).

peaksc=peaks;
troughsc=troughs;
[T N]=size(peaks);

for j=1:N
  Pt=find(peaks(:,j));
  for i=1:size(Pt)
    if Pt(i)-D <= 0
      peaksc(Pt(i),j)=0;
      %Pt(i)=D+1;
      %peaksc(Pt(i),j)=1;
    elseif Pt(i)+D >= T
      peaksc(Pt(i),j)=0;
      Pt(i)=T-D-1;
      peaksc(Pt(i),j)=1;
    end
  end
  Tt=find(troughs(:,j));
  for i=1:size(Tt)
    if Tt(i)-D <= 0
      troughsc(Tt(i),j)=0;
      %Tt(i)=D+1;
      %troughsc(Tt(i),j)=1;
    elseif Tt(i)+D >= T
      troughsc(Tt(i),j)=0;
      %Tt(i)=T-D-1;
      %troughsc(Tt(i),j)=1;
    end
  end
end
```

## C.4. DATES.M

```
function [peaks, troughs] = dates(X,D)

% function [peaks, troughs]=dates(X)
% This function determines business cycle peaks and troughs by indentifying dates at which the current
% value is higher or lower than in any other period within D periods to either side of the current observation
% in data matrix X. The standard number of periods is D=5 for monthly observations.
% This program was writen by Robert Inklaar, University of Groningen (May 2003).

[T N]=size(X);

peaks=zeros(T,N);
troughs=zeros(T,N);

for j=1:N
   for i=D+1:T-D
      % Find peaks and troughs by finding the periods that are higher or
      % lower than the D periods before and after the current period.
      if X(i,j) == max(X(i-D:i+D,j))
         peaks(i,j)=1;
      elseif X(i,j) == min(X(i-D:i+D,j))
         troughs(i,j)=1;
      end
   end
end
```

## C.5. ENFORCE.M

```
function [peakse, troughse]=enforce(X,peaks,troughs,D)

% function [peakse, troughse]=enforce(X,D,peaks,troughs)
% This function makes sure the minimum peak-to-peak and trough-to-trough period is at least 3 times the
% minimum peak-to-trough period (for monthly data this comes down to 15 months). For annual data (D=1)
% this period is changed to 2 years.
% This program was writen by Robert Inklaar, University of Groningen (May 2003).

[T N]=size(X);
peakse=peaks;
troughse=troughs;
if D==1
   Min=2;
else
   Min=3*D;
end

for j=1:N
   Pflag=0;
   Tflag=0;
   for i=1:T
      % Peak analysis
      if peakse(i,j) == 1
         if Pflag == 0
            Pflag=1;
            pv=i;
         elseif Pflag == 1
            if i-pv < Min
               if X(i,j) > X(pv,j)
                  peakse(pv,j)=0;
                  pv=i;
               elseif X(i,j) < X(pv,j)
```

```
            peakse(i,j)=0;
          else
            peakse(pv,j)=0;
            pv=i;
          end
        else
        pv=i;
        end
      end
    % Trough analysis
    elseif troughse(i,j) == 1
      if Tflag ==0
        Tflag=1;
        tv=i;
      elseif Tflag == 1
        if i-tv < Min
          if X(i,j) > X(tv,j)
            troughse(tv,j)=0;
            tv=i;
          elseif X(i,j) < X(tv,j)
            troughse(i,j)=0;
          else
            throughse(tv,j)=0;
            tv=i;
          end
        else
        tv=i;
        end
      end
    end
  end
end
```

## C.6. MA.M

```
function [Xf]=ma(X,M)

% function [Xf]=ma(X,M)
% This function calculates a centered moving average for a data matrix X (TxN) with T time series
% observations and N series with a window of M observations. The series are padded by adding the first and
% last observation M times to the data matrix. This is merely done to ensure the weights add up.
% This program was writen by Robert Inklaar, University of Groningen (May 2003).


[T N]=size(X);
for i=1:N
  Xpad=[ones(M,1)*X(1,i); X(:,i); ones(M,1)*X(T,i)];
  filt=filter(1/M*ones(1,M),1,Xpad);
  filt=filt(round(1.5*M):size(X,1)+round(1.5*M)-1);
  Xf(:,i)=filt;
end
```

## C.7. MCD.M

```
function mcdnum=mcd(X)

% function mcdnum=mcd(X)
% This function determines the number of months of cyclical dominance, with a minimum of 3 months and
% maximum of 6 months.
% This program was writen by Robert Inklaar, University of Groningen (May 2003).

[T N]=size(X);
Xs=spencer(X);
d=X-Xs;
for j=1:N
   for i=1:12
      cyc=sum(abs(d(1+i:T,j)-d(1:T-i,j)));
      tren=sum(abs(Xs(1+i:T,j)-Xs(1:T-i,j)));
      mcdv(i,j)=cyc/tren;
   end
   if find(mcdv(:,j)<1) > 0
      mcdnum(j)=min(find(mcdv(:,j)<1));
   else
      mcdnum(j)=6;
   end
end
mcdnum=min(max(mcdnum,3),6);
```

## C.8. OUTLIER.M

```
function Xclear=outlier(X)

% function Xclear=outlier(X)
% This function finds outliers by comparing the value of the original series to the value of the Spencer curve.
% If the difference between the two is more than three standard deviations the value of the original series is
% replaced by the value from the Spencer curve.
% This program was writen by Robert Inklaar, University of Groningen (May 2003).

Xs=spencer(X);
d=X-Xs;

[T N]=size(d);
dn=(d-ones(T,1)*mean(d))./(ones(T,1)*std(d));
dni=abs(dn>3);
for j=1:size(dni,2)
   for i=1:size(dni,1)
      if dni(i,j) == 1
         X(i,j)=Xs(i,j);
      end
   end
end
Xclear=X;
```

## C.9. QCD.M

```
function qcdnum=qcd(X)

% function qcdnum=qcd(X)
% This function determines the number of quarters of cyclical dominance, with a minimum of 1 quarter and
% a maximum of 2 quarters.
% This program was writen by Robert Inklaar, University of Groningen (May 2003).

[T N]=size(X);
Xs=spencer(X);
d=X-Xs;
for j=1:N
   for i=1:4
      cyc=sum(abs(d(1+i:T,j)-d(1:T-i,j)));
      tren=sum(abs(Xs(1+i:T,j)-Xs(1:T-i,j)));
      qcdv(i,j)=cyc/tren;
   end
   if find(qcdv(:,j)<1) > 0
      qcdnum(j)=min(find(qcdv(:,j)<1));
   else
      qcdnum(j)=6;
   end
end
qcdnum=min(max(qcdnum,1),2);
```

## C.10. REFINE.M

```
function [peaksref, troughsref] = refine(X, peaks, troughs, D)

% function [peaksref, troughsref] = refine(X, peaks, troughs, D)
% This functions looks in the region of the previous set of peaks and troughs (plus and minus D periods) and
% picks the peaks and troughs for the new data series.
% This program was writen by Robert Inklaar, University of Groningen (May 2003).

peaksref=peaks;
troughsref=troughs;

for j=1:size(X,2)
   Pt=find(peaks(:,j));
   for i=1:size(Pt)
      % Find the peak in the region of the previous peak
      xp=X(Pt(i)-D:Pt(i)+D,j);
      p=zeros(2*D+1,1);
      for k=1:2*D+1
         if xp(k) == max(xp)
            p(k)=1;
         end
      end
      peaksref(Pt(i)-D:Pt(i)+D,j)=p;
   end
   Tt=find(troughs(:,j));
   for i=1:size(Tt)
      % Find the trough in the region of the previous trough
      xt=X(Tt(i)-D:Tt(i)+D,j);
      t=zeros(2*D+1,1);
      for m=1:2*D+1
         if xt(m) == min(xt)
            t(m)=1;
         end
      end
```

```
      troughsref(Tt(i)-D:Tt(i)+D,j)=t;
   end
end
```

## C.11. SPENCER.M

```
function [Xs]=spencer(X)

% function [Xs]=spencer(X)
% This function calculates a Spencer curve, which is a weighted 15-months moving average. The weights are
% as follows: [-3, -6, -5, 3, 21, 46, 67, 74, 67, 46, 21, 3, -5, -6, -3]/320.
% This program was writen by Robert Inklaar, University of Groningen (May 2003).

weight=([-3 -6 -5 3 21 46 67 74 67 46 21 3 -5 -6 -3]/320)';
[T N]=size(X);
for i=1:N
   Xpad=[ones(15,1)*X(1,i); X(:,i); ones(15,1)*X(T,i)];
   filt=filter(weight,1,Xpad);
   filt=filt(23:size(X,1)+22);
   Xs(:,i)=filt;
end
```

# APPENDIX D

## D.1. FIRST ORDER CONDITIONS

### *D.1.1. Household*

Utility

$$\sum_{t=0}^{\infty}\sum_{s^t}\beta^t\pi\left(s^t\right)\left[\ln C\left(s^t\right)+\phi\ln m\left(s^t\right)-\psi L\left(s^t\right)\right]$$

$$\sum_{t=0}^{\infty}\sum_{s^t}\beta^t\pi\left(s^t\right)\left[\ln C\left(s^t\right)+\phi\ln m\left(s^t\right)-\psi L\left(s^t\right)\right]$$

Budget Constraint

$$\int_0^1 P_N\left(i,s^t\right)Y_N\left(i,s^t\right)di+\sum_{s^{t+1}}D\left(s^{t+1}\middle|s^t\right)B\left(s^{t+1}\right)+M\left(s^t\right)$$
$$\leq W\left(s^t\right)L\left(s^t\right)+\Pi\left(s^t\right)+B\left(s^t\right)+M\left(s^{t-1}\right)+T\left(s^t\right)$$

$$\max_{Y_N\left(s^t\right),m\left(s^t\right),L\left(s^t\right)} L=\sum_{t=0}^{\infty}\sum_{s^t}\beta^t\pi\left(s^t\right)\left[\ln Y_N\left(s^t\right)+\phi\ln m\left(s^t\right)-\psi L\left(s^t\right)\right]$$
$$-\lambda\left\{\int_0^1 P_N\left(i,s^t\right)Y_N\left(i,s^t\right)di+\sum_{s^{t+1}}D\left(s^{t+1}\middle|s^t\right)B\left(s^{t+1}\right)+M\left(s^t\right)\right.$$
$$\left.-W\left(s^t\right)L\left(s^t\right)+\Pi\left(s^t\right)+B\left(s^t\right)+M\left(s^{t-1}\right)+T\left(s^t\right)\right\}$$

FOC I:

$$\frac{1}{Y_N\left(s^t\right)}-\lambda\left(s^t\right)\overline{P}_N\left(s^t\right)=0$$

$$\lambda\left(s^t\right)=\frac{1}{\overline{P}_N\left(s^t\right)Y_N\left(s^t\right)}$$

FOC II:

$$-\psi+\lambda(s^t)W(s^t)=0$$

$$-\psi+\frac{W(s^t)}{\overline{P}_N(s^t)Y_N(s^t)}=0$$

FOC III:

$$\frac{\phi}{m(s^t)}-\lambda(s^t)+\beta\sum_{s^{t+1}}\pi(s^{t+1}|s^t)\lambda(s^{t+1})=0$$

$$\frac{\phi}{m(s^t)}-\frac{1}{\overline{P}_N(s^t)Y_N(s^t)}+\beta\sum_{s^{t+1}}\pi(s^{t+1}|s^t)\frac{1}{\overline{P}_N(s^{t+1})Y_N(s^{t+1})}=0$$

FOC IV:

$$\lambda\left(s^t\right)-\sum_{s^{t-1}}\beta^t\pi\left(s^t\middle|s^{t-1}\right)D\left(s^t\middle|s^{t-1}\right)\lambda\left(s^{t-1}\right)=0$$

$$\sum_{s^{t-1}} D\left(s^t \middle| s^{t-1}\right) = \beta \sum_{s^{t-1}} \pi\left(s^t \middle| s^{t-1}\right) \frac{\overline{P}_N\left(s^{t-1}\right) Y_N\left(s^{t-1}\right)}{\overline{P}_N\left(s^t\right) Y_N\left(s^t\right)}$$

Define the net nominal interest rate:

$$\frac{1}{1+r\left(s^t\right)} = \sum_{s^{t+1}} D\left(s^{t+1} \middle| s^t\right) = \beta \sum_{s^{t+1}} \pi\left(s^{t+1} \middle| s^t\right) \frac{\overline{P}_N\left(s^t\right) Y_N\left(s^t\right)}{\overline{P}_N\left(s^{t+1}\right) Y_N\left(s^{t+1}\right)}$$

Money demand:
(Take FOC III and substitute for $r(s^t)$)

$$\frac{\phi}{m(s^t)} \overline{P}_N(s^t) Y_N(s^t) + \beta \sum_{s^{t+1}} \pi(s^{t+1} \middle| s^t) \frac{\overline{P}_N(s^t) Y_N(s^t)}{\overline{P}_N(s^{t+1}) Y_N(s^{t+1})} = 1$$

$$\frac{\phi}{m(s^t)} \overline{P}_N(s^t) Y_N(s^t) + \frac{1}{1+r(s^t)} = 1$$

$$\frac{\phi}{m(s^t)} \overline{P}_N(s^t) Y_N(s^t) = 1 - \frac{1}{1+r(s^t)}$$

$$\phi \frac{\overline{P}_N(s^t) Y_N(s^t)}{m(s^t)} = \frac{r(s^t)}{1+r(s^t)}$$

$$\phi \frac{Y_N\left(s^t\right)}{m\left(s^t\right)} = \frac{r\left(s^t\right)}{1+r\left(s^t\right)}$$

Demand for final goods:

Demand for a type i good produced at stage N

$$\min \overline{P}_N\left(s^t\right) Y_N\left(s^t\right) = \int_0^1 \overline{P}_N\left(i, s^t\right) Y_N\left(i, s^t\right) di$$

s.t.

$$C(s^t) = \left[\int_0^1 Y_N\left(i, s^t\right)^{(\theta-1)/\theta} di\right]^{\theta/(\theta-1)} \equiv Y_N\left(s^t\right)$$

where,

$$\overline{P}_N\left(s^t\right) = \left[\int_0^1 P_N\left(i, s^t\right)^{1-\theta} di\right]^{1/(1-\theta)}$$

$$\min_{Y_N\left(i, s^t\right)} L = \int_0^1 P_N\left(i, s^t\right) Y_N\left(i, s^t\right) di + \lambda\left(s^t\right)\left[Y_N\left(s^t\right) - \left(\int_0^1 Y_N\left(i, s^t\right)^{(\theta-1)/\theta} di\right)^{\theta/(\theta-1)}\right]$$

$$\frac{\partial L}{\partial Y_N\left(i, s^t\right)} = P_N\left(i, s^t\right) - \lambda\left(s^t\right)\left[\int_0^1 Y_N\left(i, s^t\right)^{(\theta-1)/\theta} di\right]^{1/(\theta-1)} Y_N\left(i, s^t\right)^{1/\theta} = 0$$

$$P_N\left(i, s^t\right) = \lambda\left(s^t\right)\left[\int_0^1 Y_N\left(i, s^t\right)^{(\theta-1)/\theta} di\right]^{1/(\theta-1)} Y_N\left(i, s^t\right)^{1/\theta}$$

$$P_N\left(i, s^t\right) = \lambda\left(s^t\right) Y_N\left(s^t\right)^{\theta} Y_N\left(i, s^t\right)^{1/\theta}$$

$$Y_N\left(i,s^t\right)=\left[\frac{P_N\left(i,s^t\right)}{\lambda\left(s^t\right)}\right]^{-\theta}Y_N\left(s^t\right)$$

solve for $\lambda(s^t)$

$$Y_N\left(s^t\right)=\left[\int_0^1\left(\left(\frac{P_N\left(i,s^t\right)}{\lambda\left(s^t\right)}\right)^{-\theta}Y_N\left(s^t\right)\right)^{(\theta-1)/\theta}di\right]^{\theta/(\theta-1)}$$

$$=\left(\frac{1}{\lambda\left(s^t\right)}\right)^{-\theta}\left[\int_0^1 P_N\left(i,s^t\right)^{1-\theta}di\right]^{\theta/(\theta-1)}Y_N\left(s^t\right)$$

$$\lambda\left(s^t\right)=\left[\int_0^1 P_N\left(i,s^t\right)^{1-\theta}di\right]^{1/(1-\theta)}=\overline{P}_N\left(s^t\right)$$

substitute for $\lambda(s^t)$

$$Y_N^d\left(i,s^t\right)=\left[\frac{P_N\left(i,s^t\right)}{\overline{P}_N\left(s^t\right)}\right]^{-\theta}Y_N\left(s^t\right)$$

### *D.1.2. Firms* $n\in\{1,...,N\}$

Production Function:

$$Y_n\left(i,s^t\right)=\left[\int_0^1 Y_{n-1}\left(i,j,s^t\right)^{(\theta-1)/\theta}dj\right]^{\theta\gamma/(\theta-1)}Y_n\left(i,s^t\right)^{1-\gamma}$$

Cost minimisation:

$$\min_{Y_{n-1}\left(s^t\right),L_n\left(s^t\right)} L=\int_0^1 P_{n-1}\left(j,s^t\right)Y_{n-1}\left(i,j,s^t\right)dj+W\left(s^t\right)L_n\left(s^t\right)$$

$$-\lambda(s^t)\left[\left[\int_0^1 Y_{n-1}\left(i,j,s^t\right)^{(\theta-1)/\theta}dj\right]^{\theta\gamma/(\theta-1)}L_n\left(i,s^t\right)^{1-\gamma}-Y_n\left(i,s^t\right)\right]$$

$$\frac{\partial L}{\partial Y_{n-1}\left(i,j,s^t\right)}=$$

$$P_{n-1}\left(j,s^t\right)-\lambda\left(s^t\right)\left\{\left(\frac{\theta\gamma}{\theta-1}\right)\left[\int_0^1 Y_{n-1}\left(i,j,s^t\right)^{(\theta-1)/\theta}dj\right]^{\frac{\theta\gamma}{\theta-1}-1}\left(\frac{\theta}{\theta-1}\right)Y_{n-1}\left(i,j,s^t\right)^{-\frac{1}{\theta}}L_n\left(i,s^t\right)^{1-\gamma}\right\}=0$$

$$\frac{\partial L}{\partial L_n\left(s^t\right)}=$$

$$W\left(s^t\right)-\lambda\left(s^t\right)\left\{(1-\gamma)\left[\int_0^1 Y_{n-1}\left(i,j,s^t\right)^{(\theta-1)/\theta}dj\right]^{\frac{\theta\gamma}{\theta-1}}L_n\left(i,s^t\right)^{-\gamma}\right\}=0$$

Demand schedule: $n \in \{1, \ldots, N-1\}$

$$Y_n^d\left(i,s^t\right) = \left[\frac{\gamma}{1-\gamma}\right]^{1-\gamma} \left[\frac{P_n\left(i,s^t\right)}{\overline{P}_n\left(s^t\right)}\right]^{-\theta} \left[\frac{\overline{P}_n\left(s^t\right)}{W\left(s^t\right)}\right]^{\gamma-1} \tilde{Y}_{n+1}\left(s^t\right)$$

Aggregation:

$$\min_{\overline{Y}_{n-1}\left(s^t\right), L_n\left(s^t\right)} L = \overline{P}_{n-1}\left(s^t\right)\overline{Y}_{n-1}\left(s^t\right) + W\left(s^t\right)L_n\left(s^t\right)$$
$$-\lambda(s^t)\left[\overline{Y}_{n-1}\left(s^t\right)^{\gamma} L_n\left(s^t\right)^{1-\gamma} - \overline{Y}_n\left(s^t\right)\right]$$

FOC I

$$\frac{\partial L}{\partial \overline{Y}_{n-1}\left(s^t\right)} = \overline{P}_{n-1}\left(s^t\right) - \lambda\left(s^t\right)\left[\gamma \overline{Y}_{n-1}\left(s^t\right)^{\gamma-1} L_n\left(s^t\right)^{1-\gamma}\right] = 0$$

FOC II

$$\frac{\partial L}{\partial L_n\left(s^t\right)} = W\left(s^t\right) - \lambda\left(s^t\right)\left[(1-\gamma)\overline{Y}_{n-1}\left(s^t\right)^{\gamma} L_n\left(s^t\right)^{-\gamma}\right] = 0$$

FOC I / FOC II

$$\frac{\overline{P}_{n-1}\left(s^t\right)}{W\left(s^t\right)} = \frac{\gamma}{1-\gamma}\frac{L_n\left(s^t\right)}{\overline{Y}_{n-1}\left(s^t\right)}$$

From production function:

$$L_n\left(i,s^t\right) = Y_n\left(i,s^t\right)^{1/(1-\gamma)} \overline{Y}_{n-1}\left(s^t\right)^{\gamma/(\gamma-1)}$$
$$\overline{Y}_{n-1}\left(s^t\right) = Y_n\left(i,s^t\right)^{1/\gamma} L_n\left(i,s^t\right)^{(\gamma-1)/\gamma}$$

Total cost:

$$\begin{aligned}
TC\left(s^t\right) &= \overline{P}_{n-1}\left(s^t\right)\overline{Y}_{n-1}\left(s^t\right) + W\left(s^t\right)L_n\left(s^t\right) \\
&= \overline{P}_{n-1}\left(s^t\right)\left[\frac{\gamma}{1-\gamma}\frac{W\left(s^t\right)}{\overline{P}_{n-1}\left(s^t\right)}\right]^{1-\gamma} Y_n\left(i,s^t\right) + W\left(s^t\right)\left[\frac{\gamma}{1-\gamma}\frac{W\left(s^t\right)}{\overline{P}_{n-1}\left(s^t\right)}\right]^{-\gamma} Y_n\left(i,s^t\right) \\
&= \left(\frac{\gamma}{1-\gamma}\right)^{1-\gamma} \overline{P}_{n-1}\left(s^t\right)^{\gamma} W\left(s^t\right)^{1-\gamma} Y_n\left(i,s^t\right) + \left(\frac{\gamma}{1-\gamma}\right)^{-\gamma} \overline{P}_{n-1}\left(s^t\right)^{\gamma} W\left(s^t\right)^{1-\gamma} Y_n\left(i,s^t\right) \\
&= \left[\left(\frac{\gamma}{1-\gamma}\right)^{1-\gamma} + \left(\frac{\gamma}{1-\gamma}\right)^{-\gamma}\right]\overline{P}_{n-1}\left(s^t\right)^{\gamma} W\left(s^t\right)^{1-\gamma} Y_n\left(i,s^t\right) \\
&= \gamma^{-\gamma}\left(1-\gamma\right)^{-(1-\gamma)} \overline{P}_{n-1}\left(s^t\right)^{\gamma} W\left(s^t\right)^{1-\gamma} Y_n\left(i,s^t\right) \\
&= \tilde{\gamma}\overline{P}_{n-1}\left(s^t\right)^{\gamma} W\left(s^t\right)^{1-\gamma} Y_n\left(i,s^t\right)
\end{aligned}$$

Marginal cost:

$$MC\left(s^t\right)=\frac{TC\left(s^t\right)}{Y_n\left(i,s^t\right)}=\tilde{\gamma}\overline{P}_{n-1}\left(s^t\right)^{\gamma}W\left(s^t\right)^{1-\gamma}$$

Profit Maximisation problem:

$$\max_{P_n\left(i,s^t\right)}\sum_{\tau=t}^{t+1}\sum_{s^\tau}D\left(s^\tau\left|s^t\right.\right)\left[P_n\left(i,s^t\right)-V_n\left(i,s^\tau\right)\right]Y_n^d\left(i,s^\tau\right)$$

$$\frac{\partial}{\partial P_n\left(i,s^t\right)}=\left(1-\theta\right)\sum_{\tau=t}^{t+1}\sum_{s^\tau}D\left(s^\tau\left|s^t\right.\right)Y_n^d\left(i,s^\tau\right)+\theta\sum_{\tau=t}^{t+1}\sum_{s^\tau}D\left(s^\tau\left|s^t\right.\right)Y_n^d\left(i,s^\tau\right)V_n\left(i,s^\tau\right)P_n\left(i,s^t\right)^{-1}=0$$

$$\left(\theta-1\right)\sum_{\tau=t}^{t+1}\sum_{s^\tau}D\left(s^\tau\left|s^t\right.\right)Y_n^d\left(i,s^\tau\right)P_n\left(i,s^t\right)=\theta\sum_{\tau=t}^{t+1}\sum_{s^\tau}D\left(s^\tau\left|s^t\right.\right)Y_n^d\left(i,s^\tau\right)V_n\left(i,s^\tau\right)$$

Optimal pricing equation: $n\in\left\{1,\ldots,N\right\}$

$$P_n\left(i,s^t\right)=\frac{\theta}{\left(\theta-1\right)}\frac{\sum_{\tau=t}^{t+1}\sum_{s^\tau}D\left(s^\tau\left|s^t\right.\right)Y_n^d\left(i,s^\tau\right)V_n\left(i,s^\tau\right)}{\sum_{\tau=t}^{t+1}\sum_{s^\tau}D\left(s^\tau\left|s^t\right.\right)Y_n^d\left(i,s^\tau\right)}$$

## D.2. STEADY-STATES

Labour supply decision

$$W*=\psi C*\overline{P_N}*$$

Money Demand

$$\phi\frac{Y_N*\overline{P_N}*}{m*}=1-\beta$$

Euler Equation

$$1=\beta\left(1+r*\right)$$

Demand for Final Goods

$$1=\left[\frac{P_N*}{\overline{P_N}*}\right]^{-\theta}$$

Production Function

$$Y_n*=\left(\overline{Y_{n-1}}*\right)^{\gamma}\left(L_n*\right)^{1-\gamma}$$

Unit cost

$$V^{*} = \gamma\left(\overline{P_{n-1}}*\right)^{\gamma}\left(W*\right)^{1-\gamma}$$

Demand for Intermediate Goods

$$Y_n * = \left(\frac{\gamma}{1-\gamma}\right)^{1-\gamma}\left(\frac{P_n *}{\overline{P_n} *}\right)^{-\theta}\left(\frac{\overline{P_n} *}{W *}\right)^{\gamma-1} Y_{n+1} *$$

Optimal Pricing Equation

$$\left(\theta-1\right)\beta Y_n * P_n * = \theta\beta Y_n * V_n *$$

Budget Constraint

$$\overline{P_N} * + Y_N * = W * + L * + \Pi *$$

## D.3. LOG-LINEARIZATION

System of conveniently ordered log-linearized equations. Assuming there are multiple stages of production, n ϵ {1,…,N} and firms at each stage set prices for two periods.

Labour supply decision

(D.1) $$0 = y_N\left(t\right) + \frac{1}{2}\left[p_N\left(t-1\right) + p_N\left(t\right)\right] - w\left(t\right)$$

Production function; n ϵ {1,…,N}

(D.2) $$0 = y_1\left(t\right) - l_1\left(t\right)$$

(D.3) $$0 = y_2\left(t\right) - \gamma\left[\frac{1}{2}\left[y_1\left(t-1\right) - y_1\left(t\right)\right]\right] - \left(1-\gamma\right)l_2\left(t\right)$$

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(D.4) $$0 = y_{N-1}\left(t\right) - \gamma\left[\frac{1}{2}\left[y_{N-2}\left(t-1\right) - y_{N-2}\left(t\right)\right]\right] - \left(1-\gamma\right)l_{N-1}\left(t\right)$$

(D.5) $$0 = y_N\left(t\right) - \gamma\left[\frac{1}{2}\left[y_{N-1}\left(t-1\right) - y_{N-1}\left(t\right)\right]\right] - \left(1-\gamma\right)l_N\left(t\right)$$

Marginal cost; n ϵ {1,…,N}

(D.6) $$0 = v_1\left(t\right) - w\left(t\right)$$

(D.7) $$0 = v_2\left(t\right) - \gamma\left[\frac{1}{2}\left[p_1\left(t-1\right) - p_1\left(t\right)\right]\right] - \left(1-\gamma\right)w\left(t\right)$$

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(D.8) $$0 = v_{N-1}(t) - \gamma\left[\frac{1}{2}\left[p_{N-2}(t-1) - p_{N-2}(t)\right]\right] - (1-\gamma)w(t)$$

(D.9) $$0 = v_N(t) - \gamma\left[\frac{1}{2}\left[p_{N-1}(t-1) - p_{N-1}(t)\right]\right] - (1-\gamma)w(t)$$

Demand for intermediate goods; n ϵ {1,…,N-1}

(D.10)
$$0 = \frac{1}{2}\left[3\theta + (\gamma-1)\right]p_1(t) + \frac{1}{2}\left[\theta + (\gamma-1)\right]p_1(t-1) + (1-\gamma)w(t) + \frac{1}{2}\left[y_2(t-1) + y_2(t)\right] - y_1(t)$$

(D.11)
$$0 = \frac{1}{2}\left[3\theta + (\gamma-1)\right]p_2(t) + \frac{1}{2}\left[\theta + (\gamma-1)\right]p_2(t-1) + (1-\gamma)w(t) + \frac{1}{2}\left[y_3(t-1) + y_3(t)\right] - y_2(t)$$

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(D.12)
$$0 = \frac{1}{2}\left[3\theta + (\gamma-1)\right]p_{N-1}(t) + \frac{1}{2}\left[\theta + (\gamma-1)\right]p_{N-1}(t-1) + (1-\gamma)w(t) + \frac{1}{2}\left[y_N(t-1) + y_N(t)\right] - y_{N-1}(t)$$

Demand for final goods; n = N

(D.13) $$0 = \theta\left[\frac{1}{2}\left(p_N(t-1) - p_N(t)\right)\right]$$

Money demand

(D.14)
$$0 = (1-\beta)m(t) - y_N(t) - \frac{1}{2}\left[p_N(t-1) + p_N(t)\right] + \beta \mathrm{E}_t\left[\frac{1}{2}\left[p_N(t) + p_N(t+1)\right] + y_N(t+1)\right]$$

Optimal price decision; n ϵ {1,…,N}

(D.15) $$0 = \frac{1}{1+\beta}w(t) + \frac{\beta}{1+\beta}\mathrm{E}_t\left[w(t+1)\right] - p_1(t)$$

(D.16) $$\begin{aligned} 0 = &\frac{1}{1+\beta}\left[\gamma\left[\frac{1}{2}\left[p_1(t-1) + p_1(t)\right]\right] + (1-\gamma)w(t)\right] - p_2(t) \\ &+ \frac{\beta}{1+\beta}\mathrm{E}_t\left[\gamma\left[\frac{1}{2}\left[p_1(t) + p_1(t+1)\right]\right] + (1-\gamma)w(t+1)\right] \end{aligned}$$

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(D.17)

$$0 = \frac{1}{1+\beta}\left[\gamma\left[\frac{1}{2}\left[p_{N-2}(t-1)+p_{N-2}(t)\right]\right]+\left(1-\gamma\right)w(t)\right]-p_{N-1}(t)$$
$$+\frac{\beta}{1+\beta}\mathrm{E}_t\left[\gamma\left[\frac{1}{2}\left[p_{N-2}(t)+p_{N-2}(t+1)\right]\right]+\left(1-\gamma\right)w(t+1)\right]$$

(D.18)

$$0 = \frac{1}{1+\beta}\left[\gamma\left[\frac{1}{2}\left[p_{N-1}(t-1)+p_{N-1}(t)\right]\right]+\left(1-\gamma\right)w(t)\right]-p_{N}(t)$$
$$+\frac{\beta}{1+\beta}\mathrm{E}_t\left[\gamma\left[\frac{1}{2}\left[p_{N-1}(t)+p_{N-1}(t+1)\right]\right]+\left(1-\gamma\right)w(t+1)\right]$$

Euler equation
(D.19)

$$0 = \beta\left(1+r*\right)\mathrm{E}_t\left[\frac{1}{2}\left[p_N(t)+p_N(t+1)\right]+y_N(t+1)\right]-y_N(t)-\frac{1}{2}\left[p_N(t-1)+p_N(t)\right]$$

Money supply
(D.20) $$m(t+1)=m(t)+\varepsilon(t+1)$$

## D.4. UHLIG (1997) DECOMPOSITION

Endogenous state variables x(t): [$y_1$(t),…, $y_N$(t), $p_1$(t),…, $p_N$(t)]

Endogenous other variables y(t): [$v_1$(t),…, $v_N$(t), $l_1$(t),…, $l_N$(t), w(t)]

Exogenous state variables z(t): [m(t)]

(D.21)
$$0 = AAx(\mathrm{t}) + BBx(\mathrm{t\text{-}1}) + CCy(\mathrm{t}) + DDz(\mathrm{t})$$

(D.22)
$$0 = \mathrm{E}_t\left[FFx(\mathrm{t+1}) + GGx(\mathrm{t}) + HHx(\mathrm{t\text{-}1}) + JJy(\mathrm{t+1})KKy(\mathrm{t}) + LLz(\mathrm{t+1}) + MMz(\mathrm{t})\right]$$

(D.23)
$$z(\mathrm{t+1}) = NN\mathrm{z}(\mathrm{t}) + \varepsilon(\mathrm{t+1})$$

Deterministic equations (D.1)-(D.13):

$$\begin{bmatrix}
y_1 & y_2 & \cdots & y_{N-1} & y_N & p_1 & p_2 & \cdots & p_{N-1} & p_N & eq^n & n = \\
 & & \cdots & & & & & \cdots & & & (\mathrm{A.1}) & N \\
 & & \cdots & & & & & \cdots & & & (\mathrm{A.2}) & 1 \\
 & & \cdots & & & & & \cdots & & & (\mathrm{A.3}) & 2 \\
\vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots \\
 & & \cdots & & & & & \cdots & & & (\mathrm{A.4}) & N-1 \\
 & & \cdots & & & & & \cdots & & & (\mathrm{A.5}) & N \\
 & & \cdots & & & & & \cdots & & & (\mathrm{A.6}) & 1 \\
 & & \cdots & & & & & \cdots & & & (\mathrm{A.7}) & 2 \\
\vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots \\
 & & \cdots & & & & & \cdots & & & (\mathrm{A.8}) & N-1 \\
 & & \cdots & & & & & \cdots & & & (\mathrm{A.9}) & N \\
 & & \cdots & & & & & \cdots & & & (\mathrm{A.10}) & 1 \\
 & & \cdots & & & & & \cdots & & & (\mathrm{A.11}) & 2 \\
\vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots \\
 & & \cdots & & & & & \cdots & & & (\mathrm{A.12}) & N-1 \\
 & & \cdots & & & & & \cdots & & & (\mathrm{A.13}) & N
\end{bmatrix}$$

For $x(t) = [y_1(t), y_2(t),\ldots, y_{N-1}(t), y_N(t), p_1(t), p_2(t),\ldots, p_{N-1}(t), p_N(t)]$

$$AA=\begin{bmatrix}
0 & 0 & \cdots & 0 & 1 & 0 & 0 & \cdots & 0 & \frac{1}{2}\\
1 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0\\
-\frac{\gamma}{2} & 1 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0\\
\vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots\\
0 & 0 & \cdots & 1 & 0 & 0 & 0 & \cdots & 0 & 0\\
0 & 0 & \cdots & -\frac{\gamma}{2} & 1 & 0 & 0 & \cdots & 0 & 0\\
0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0\\
0 & 0 & \cdots & 0 & 0 & -\frac{\gamma}{2} & 0 & \cdots & 0 & 0\\
\vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots\\
0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0\\
0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & -\frac{\gamma}{2} & 0\\
-1 & \frac{1}{2} & \cdots & 0 & 0 & \frac{3\theta+(\gamma-1)}{2} & 0 & \cdots & 0 & 0\\
0 & -1 & \cdots & 0 & 0 & 0 & \frac{3\theta+(\gamma-1)}{2} & \cdots & 0 & 0\\
\vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots\\
0 & 0 & \cdots & -1 & \frac{1}{2} & 0 & 0 & \cdots & \frac{3\theta+(\gamma-1)}{2} & 0\\
0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & \frac{\theta}{2}
\end{bmatrix}$$

For x(t-1) = [$y_1$(t-1), $y_2$(t-1),…,$y_{N-1}$(t-1),$y_N$(t-1), $p_1$(t-1),$p_2$(t-1),…, $p_{N-1}$(t-1), $p_N$(t-1)]

$$BB=\begin{bmatrix}
0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & \frac{1}{2} \\
0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0 \\
-\frac{\gamma}{2} & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0 \\
\vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\
0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0 \\
0 & 0 & \cdots & -\frac{\gamma}{2} & 0 & 0 & 0 & \cdots & 0 & 0 \\
0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0 \\
0 & 0 & \cdots & 0 & 0 & -\frac{\gamma}{2} & 0 & \cdots & 0 & 0 \\
\vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\
0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0 \\
0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & -\frac{\gamma}{2} & 0 \\
-1 & \frac{1}{2} & \cdots & 0 & 0 & \frac{\theta+(\gamma-1)}{2} & 0 & \cdots & 0 & 0 \\
0 & -1 & \cdots & 0 & 0 & 0 & \frac{\theta+(\gamma-1)}{2} & \cdots & 0 & 0 \\
\vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\
0 & 0 & \cdots & -1 & \frac{1}{2} & 0 & 0 & \cdots & \frac{\theta+(\gamma-1)}{2} & 0 \\
0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & \frac{\theta}{2}
\end{bmatrix}$$

For y(t) = [$v_1$(t), $v_2$(t),…, $v_{N-1}$(t), $v_N$(t), $l_1$(t), $l_2$(t),…, $l_{N-1}$(t), $l_N$(t), w(t)]

$$CC = \begin{bmatrix} 0 & 0 & \ldots & 0 & 0 & 0 & 0 & \ldots & 0 & 0 & -1 \\ 0 & 0 & \ldots & 0 & 0 & -1 & 0 & \ldots & 0 & 0 & 0 \\ 0 & 0 & \ldots & 0 & 0 & 0 & \gamma-1 & \ldots & 0 & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ 0 & 0 & \ldots & 0 & 0 & 0 & 0 & \ldots & \gamma-1 & 0 & 0 \\ 0 & 0 & \ldots & 0 & 0 & 0 & 0 & \ldots & 0 & \gamma-1 & 0 \\ 1 & 0 & \ldots & 0 & 0 & 0 & 0 & \ldots & 0 & 0 & -1 \\ 0 & 1 & \ldots & 0 & 0 & 0 & 0 & \ldots & 0 & 0 & \gamma-1 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ 0 & 0 & \ldots & 1 & 0 & 0 & 0 & \ldots & 0 & 0 & \gamma-1 \\ 0 & 0 & \ldots & 0 & 1 & 0 & 0 & \ldots & 0 & 0 & \gamma-1 \\ 0 & 0 & \ldots & 0 & 0 & 0 & 0 & \ldots & 0 & 0 & 1-\gamma \\ 0 & 0 & \ldots & 0 & 0 & 0 & 0 & \ldots & 0 & 0 & 1-\gamma \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ 0 & 0 & \ldots & 0 & 0 & 0 & 0 & \ldots & 0 & 0 & 1-\gamma \\ 0 & 0 & \ldots & 0 & 0 & 0 & 0 & \ldots & 0 & 0 & 0 \end{bmatrix}$$

For z(t) = [m(t)]

$$DD = \begin{bmatrix} 0 \\ 0 \\ 0 \\ \vdots \\ 0 \\ 0 \\ 0 \\ 0 \\ \vdots \\ 0 \\ 0 \\ 0 \\ 0 \\ \vdots \\ 0 \\ 0 \end{bmatrix}$$

Expectation equations (D.14)-(D.19)

For $x(t+1) = [y_1(t+1), y_2(t+1),\ldots, y_{N-1}(t+1), y_N(t+1), p_1(t+1), p_2(t+1),\ldots, p_{N-1}(t+1), p_N(t+1)]$

$$FF = \begin{bmatrix} 0 & 0 & \cdots & 0 & \beta & 0 & 0 & \cdots & 0 & \frac{\beta}{2} \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 0 & \cdots & 0 & 0 & \left(\frac{\gamma}{2}\right)\frac{\beta}{1+\beta} & 0 & \cdots & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & \left(\frac{\gamma}{2}\right)\frac{\beta}{1+\beta} & 0 \\ 0 & 0 & \cdots & 0 & \beta(1+r^*) & 0 & 0 & \cdots & 0 & \frac{\beta(1+r^*)}{2} \end{bmatrix}$$

For $x(t) = [y_1(t), y_2(t),\ldots, y_{N-1}(t), y_N(t), p_1(t), p_2(t),\ldots, p_{N-1}(t), p_N(t)]$

$$GG = \begin{bmatrix} 0 & 0 & \cdots & 0 & -1 & 0 & 0 & \cdots & 0 & \frac{\beta-1}{2} \\ 0 & 0 & \cdots & 0 & 0 & -1 & 0 & \cdots & 0 & 0 \\ 0 & 0 & \cdots & 0 & 0 & \frac{\gamma}{2} & -1 & \cdots & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & -1 & 0 \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & \frac{\gamma}{2} & -1 \\ 0 & 0 & \cdots & 0 & -1 & 0 & 0 & \cdots & 0 & \frac{\beta(1+r^*)}{2}-\frac{1}{2} \end{bmatrix}$$

For x(t-1) = [$y_1$(t-1), $y_2$(t-1),…,$y_{N-1}$(t-1),$y_N$(t-1), $p_1$(t-1),$p_2$(t-1),…, $p_{N-1}$(t-1), $p_N$(t-1)]

$$HH = \begin{bmatrix} 0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & -\frac{1}{2} \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 0 & \cdots & 0 & 0 & \left(\frac{\gamma}{2}\right)\frac{1}{1+\beta} & 0 & \cdots & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & \left(\frac{\gamma}{2}\right)\frac{1}{1+\beta} & 0 \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & -\frac{1}{2} \end{bmatrix}$$

For y(t+1) = [$v_1$(t+1), $v_2$(t+1),…, $v_{N-1}$(t+1), $v_N$(t+1), $l_1$(t+1), $l_2$(t+1),…, $l_{N-1}$(t+1), $l_N$(t+1), w(t+1)]

$$JJ = \begin{bmatrix} 0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & \frac{\beta}{1+\beta} \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & \frac{\beta(1-\gamma)}{1+\beta} \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & \frac{\beta(1-\gamma)}{1+\beta} \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & \frac{\beta(1-\gamma)}{1+\beta} \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 \end{bmatrix}$$

For y(t) = [$v_1$(t), $v_2$(t),…, $v_{N-1}$(t), $v_N$(t), $l_1$(t), $l_2$(t),…, $l_{N-1}$(t), $l_N$(t), w(t)]

$$KK = \begin{bmatrix} 0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & \dfrac{1}{1+\beta} \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & \dfrac{(1-\gamma)}{1+\beta} \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & \dfrac{(1-\gamma)}{1+\beta} \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & \dfrac{(1-\gamma)}{1+\beta} \\ 0 & 0 & \cdots & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 \end{bmatrix}$$

For z(t+1) = [m(t+1)]

$$LL = \begin{bmatrix} 0 \\ 0 \\ 0 \\ \vdots \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

For z(t) = [m(t)]

$$MM = \begin{bmatrix} 1-\beta \\ 0 \\ 0 \\ \vdots \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

Autoregressive matrix, from equation (D.20)
For z(t) = [m(t)]

$$NN = [1]$$

$$\sigma = \left[\sigma\varepsilon^2\right]$$

# APPENDIX E

## E.1. DIAGNOSTICS AND RESIDUAL PLOTS

### *E.1.1. Relationship between Output Persistence, GDP per capita and Energy Use per capita.*

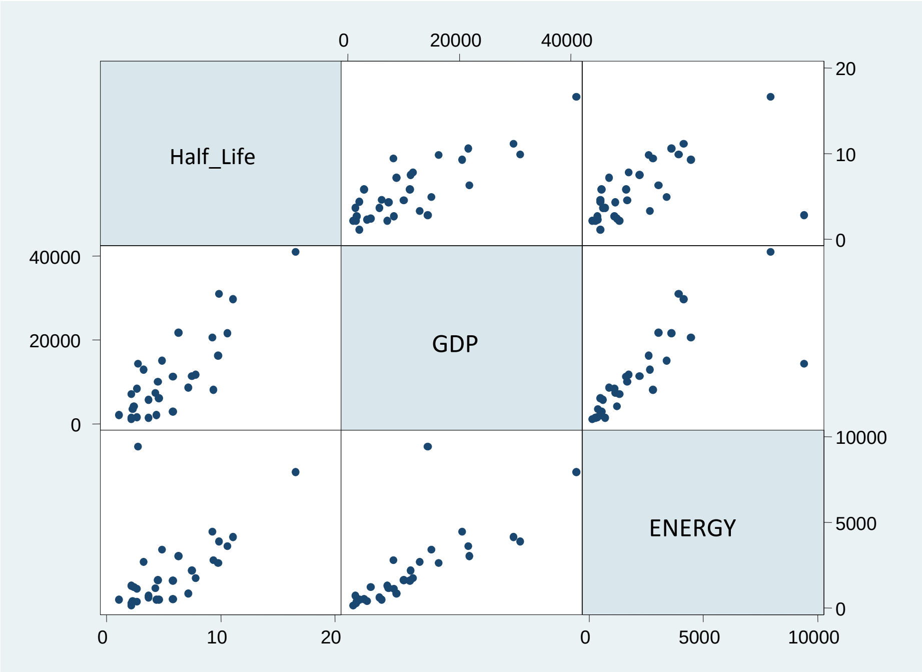


**Figure E.1 Scatterplot: Output Persistence, GDP per capita, Energy Use per capita**

**Table E.1**
**Regression Results: Relationship between Output Persistence and Economic Development**

| | **Model 1** | | | | **Model 2** | | | | **Model 3** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | A | B | C | D | A | B | C | D |
| Ln[GDP] | 2.396** | 2.008** | 2.494** | 2.112** | | | | | 2.681* | 2.477* | 1.278 | 1.341 |
| | (0.421) | (0.380) | (0.405) | (0.364) | | | | | (1.109) | (0.959) | (1.185) | (1.032) |
| Ln[Energy] | | | | | 2.261** | 1.806** | 2.797** | 2.341** | -0.111 | -0.362 | 1.568 | 1.046 |
| | | | | | (0.496) | (0.459) | (0.454) | (0.428) | (1.083) | (0.938) | (1.227) | (1.082) |
| Constant | -15.597** | -12.414** | -16.312** | -13.186** | -10.617** | -7.599* | -14.206** | -11.175** | -17.419** | -14.035** | -16.779** | -13.850** |
| | (3.749) | (3.359) | (3.600) | (3.212) | (3.618) | (3.319) | (3.278) | (3.057) | (4.367) | (3.914) | (4.047) | (3.652) |
| $R^2$ | 0.528 | 0.500 | 0.575 | 0.555 | 0.426 | 0.364 | 0.584 | 0.535 | 0.528 | 0.494 | 0.602 | 0.565 |
| F | 32.39** | 27.94** | 37.87** | 33.61** | 20.76** | 15.45** | 37.94** | 29.96** | 15.09** | 12.68** | 19.67** | 16.22** |
| Breusch-Pagan | 4.53* | 2.02 | 3.52 | 1.17 | 14.30** | 9.37* | 3.99* | 1.81 | 3.65 | 1.19 | 1.18 | 1.17 |
| RESET | 5.7** | 1.88 | 5.50* | 1.98 | 1.52 | 4.28* | 4.79** | 1.47 | 4.88** | 1.94 | 1.94 | 2.32 |

Significance is denoted by: * if p<0.05 and ** if p<0.01
Standard errors are reported in brackets.

A: All countries are included in the regression
B: The US is excluded from the regression
C: Trinidad & Tobago are excluded from the regression.
D: Both the US and Trinidad & Tobago are excluded from the regression.

Breusch-Pagan is Breusch-Pagan test for heteroscedasticity. Ho: constant variance.
RESET is Ramsey RESET specification test. Ho: model has no omitted variables

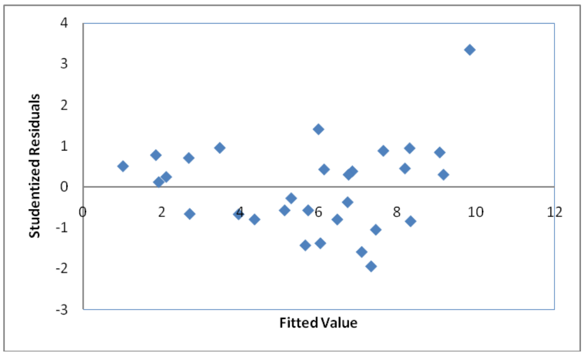


**Figure E.2** **Residual Plot: Model 1(A)**

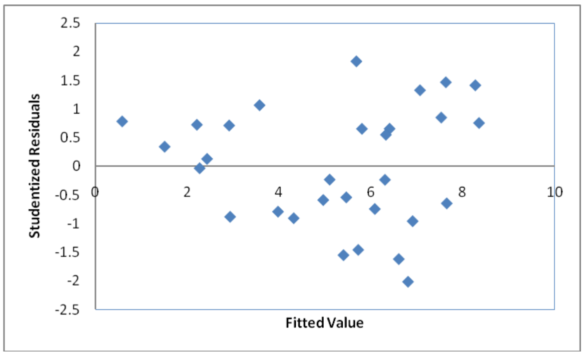


**Figure E.3** **Residual Plot: Model 1(B)**

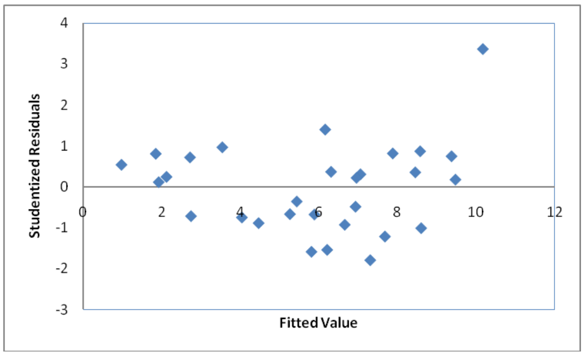


**Figure E.4** **Residual Plot: Model 1(C)**

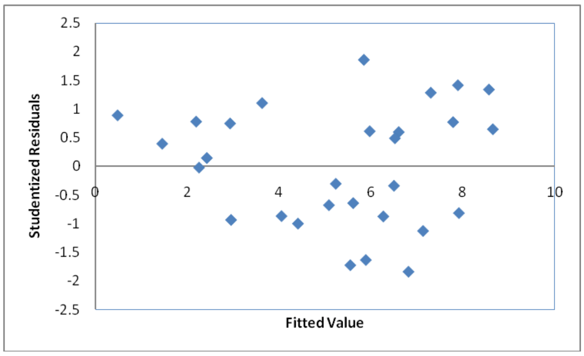


**Figure E.5** **Residual Plot: Model 1(D)**

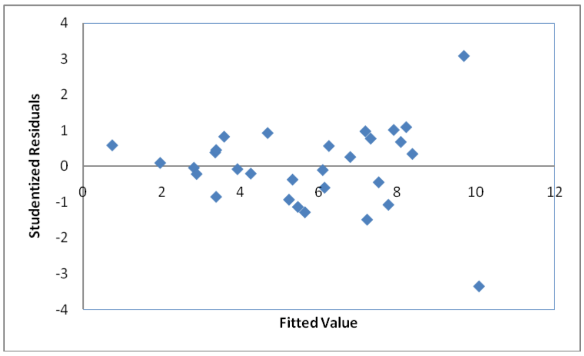


**Figure E.6** **Residual Plot: Model 2(A)**

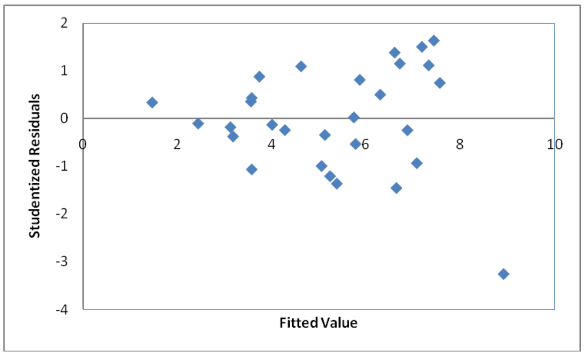


**Figure E.7** **Residual Plot: Model 2(B)**

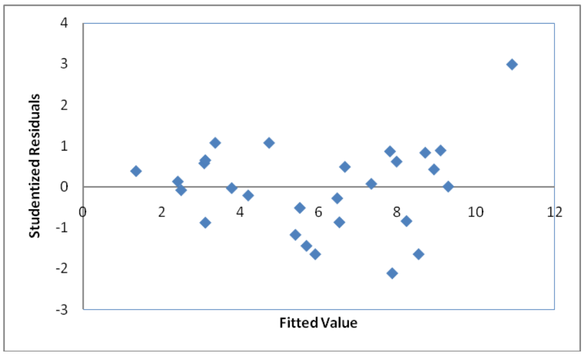


**Figure E.8** **Residual Plot: Model 2(C)**

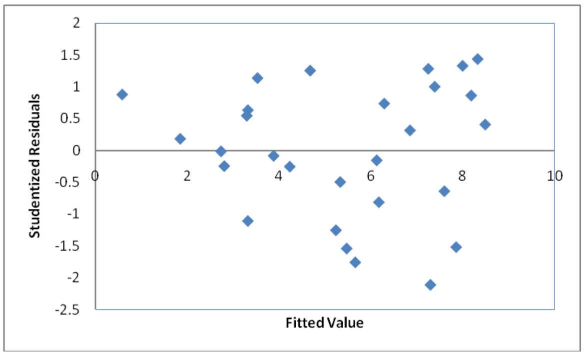


**Figure E.9** **Residual Plot: Model 2(D)**

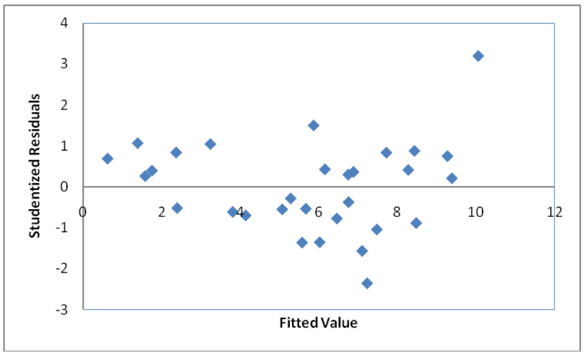


**Figure E.10** **Residual Plot: Model 3(A)**

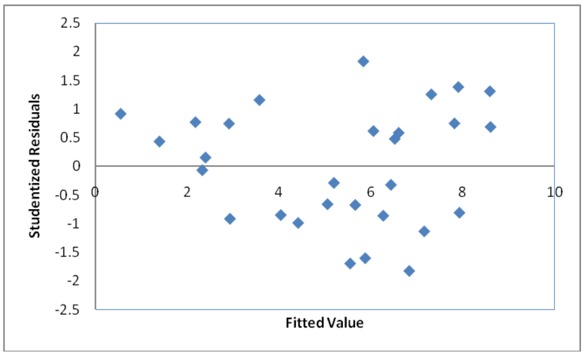


**Figure E.11** **Residual Plot: Model 3(B)**

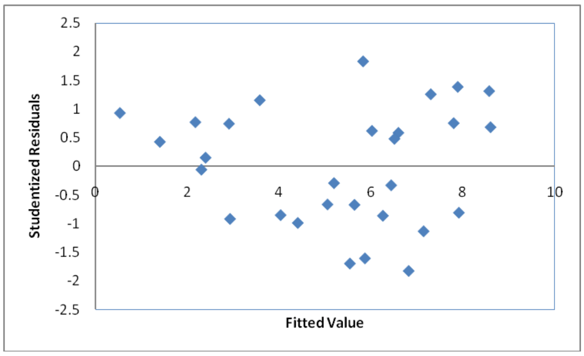


**Figure E.12** **Residual Plot: Model 3(C)**

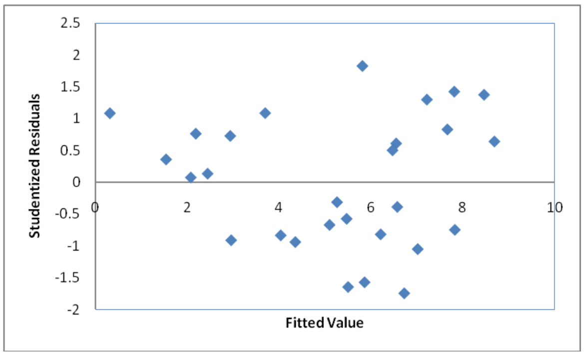


**Figure E.13** **Residual Plot: Model 3(D)**

## *E.1.2. Relationship between Difference and Inflation.*

**Table E.2**

**Regression Results: Relationship between Difference and Inflation**

| | A | B | C | D |
|---|---|---|---|---|
| HIGH | -3.574*<br>(1.315) | -3.851**<br>(1.313) | -2.370**<br>(0.550) | -2.583**<br>(0.504) |
| Constant | 2.231**<br>(0.778) | 2.508**<br>(0.797) | 1.027**<br>(0.343) | 1.240**<br>(0.324) |
| $R^2$ | 0.291 | 0.336 | 0.538 | 0.636 |
| F | 7.38* | 8.60** | 18.95** | 26.24** |
| Breusch-Pagan | 3.81 | 3.85* | 1.60 | 1.19 |
| RESET | … | … | … | … |

Significance is denoted by: * if p<0.05 and ** if p<0.01
Standard errors are reported in brackets.

A: All countries are included in the regression
B: Slovak Republic is excluded from the regression
C: The US and UK are excluded from the regression
D: The US and UK and Slovak Republic are excluded from the regression

Breusch-Pagan is Breusch-Pagan test for heteroscedasticity. Ho: constant variance.
RESET is Ramsey RESET specification test. Ho: model has no omitted variables.

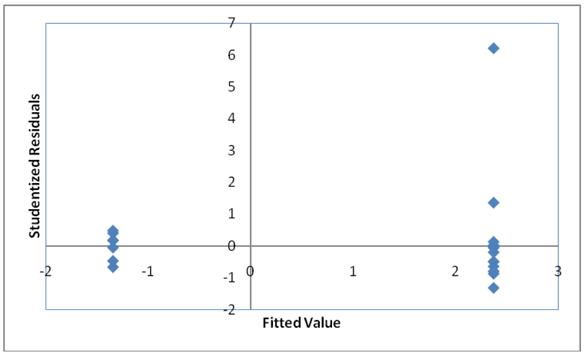


**Figure E.14** **Residual Plot: Difference (Model A)**

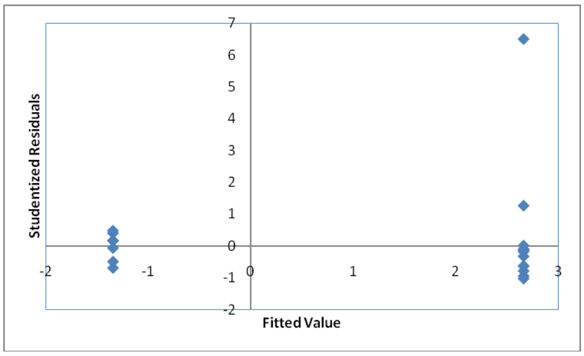


**Figure E.15** **Residual Plot: Difference (Model B)**

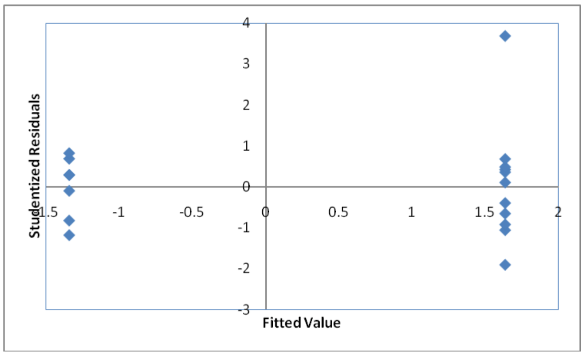


**Figure E.16 Residual Plot: Difference (Model C)**

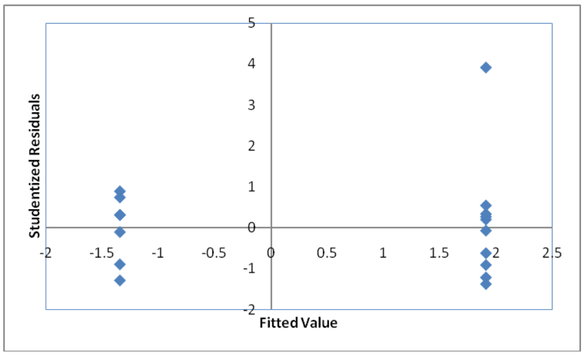


**Figure E.17 Residual Plot: Difference (Model D)**

### *E.1.3. Relationship between Model Half-Life, GDP per capita and Energy Use per capita.*

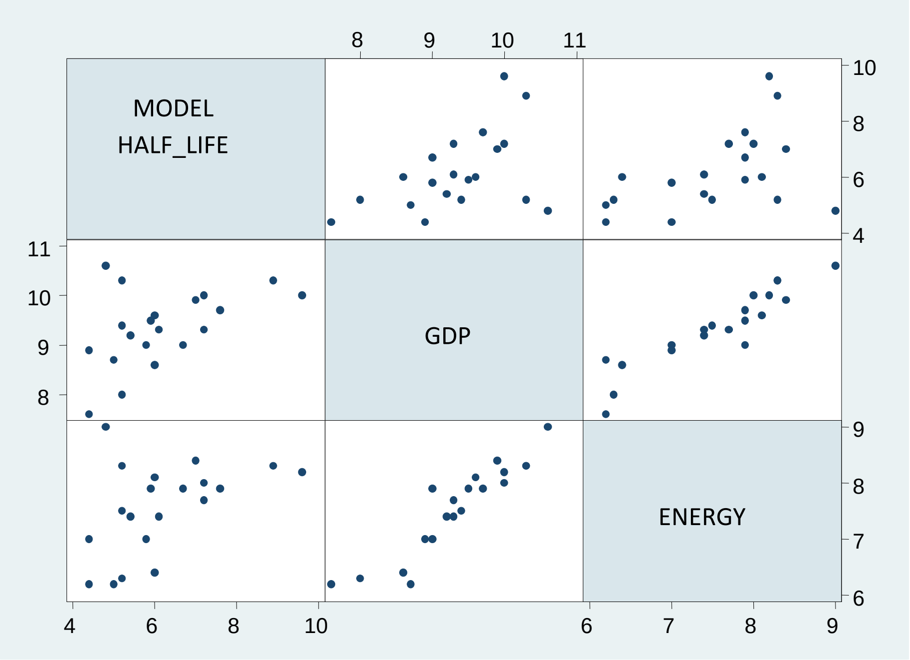


**Figure E.18 Scatterplot: Model Half-Life, GDP per capita, Energy Use per capita**

**Table E.3**

**Regression Results: Relationship between Model Half-Life and Economic Development**

| | Model 1 | | Model 2 | |
|---|---|---|---|---|
| | A | B | A | B |
| Ln[GDP] | 0.942* (0.373) | 1.611** (0.310) | | |
| Ln[Energy Use] | | | 0.883* (0.353) | 1.468** (0.301) |
| Constant | -2.623 (3.497) | -8.542** (2.871) | -0.491 (2.678) | -4.600 (2.248) |
| $R^2$ | 0.262 | 0.627 | 0.258 | 0.598 |
| F | 6.38* | 26.91** | 6.27* | 23.79* |
| Breusch-Pagan | 7.47** | 0.86 | 6.56** | 1.80 |
| RESET | 2.78 | 1.82 | 2.75 | 1.59 |

Significance is denoted by: * if p<0.05 and ** if p<0.01
Standard errors are reported in brackets.

A: All countries are included in the regression
B: The US and UK are excluded from the regression

Breusch-Pagan is Breusch-Pagan test for heteroscedasticity. Ho: constant variance.
RESET is Ramsey RESET specification test. Ho: model has no omitted variables.

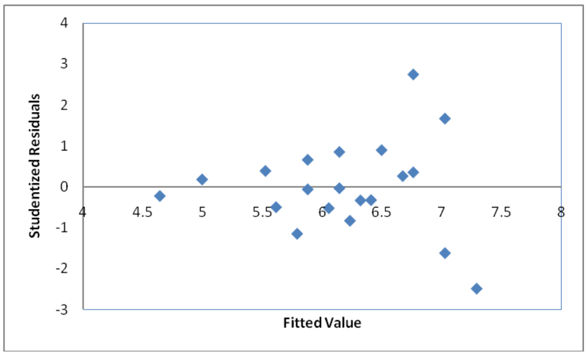


**Figure E.19 Residual Plot: Model 1(A) (Model HL)**

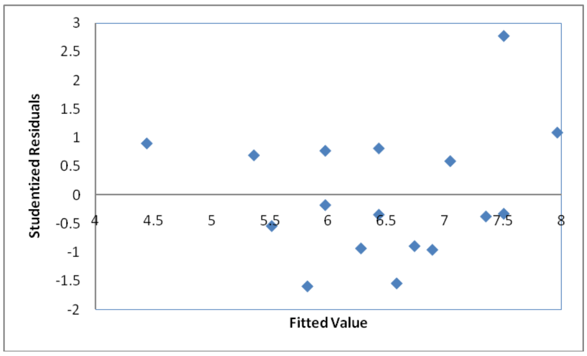


**Figure E.20 Residual Plot: Model 1(B) (Model HL)**

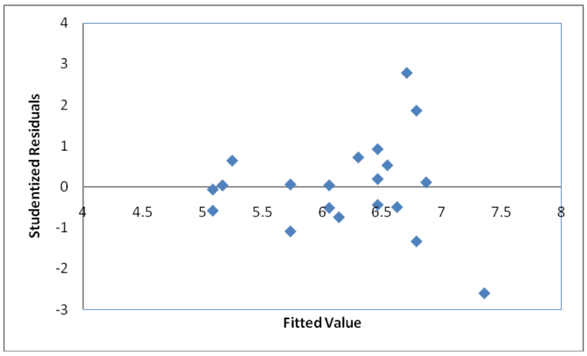


**Figure E.21** **Residual Plot: Model 2(A) (Model HL)**

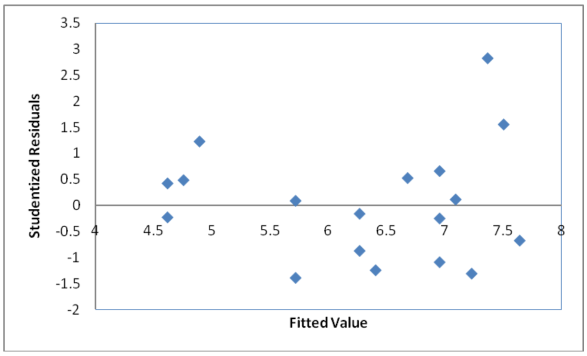


**Figure E.22** **Residual Plot: Model 2(B) (Model HL)**