The role of real and nominal variables in defining business cycles: dynamic properties of a hybrid model - an alternative view

Chirwa, Themba G.

Millennium Challenge Account - Malawi Country Office

October 2009

The role of real and nominal variables in defining business cycles:

dynamic properties of a hybrid model - an alternative view

Themba Gilbert Chirwa*[a]

currently working for Millennium Challenge Account – Malawi (A Project under Ministry of Finance), P. O. Box 31513, Lilongwe, Malawi, Central Africa

Abstract

The paper provides an alternative view to the Real and New Keynesian business cycle theories. The paper focuses on the combination of both real and nominal variables in explaining the cyclical movements of business cycles. We propose using Vector Autoregressive (VAR) technique on the production function approach in order to empirically assess the relative importance of both real and nominal variables in defining the shape of a business cycle (or output gap). An economy-specific variable (inflation) is introduced in the production function and is used to control the severity, persistence and magnitude of a given real shock. The model employed is tested in four countries namely: United States of America, United Kingdom, Canada and Germany. The results show that indeed real and nominal variables play an important and major role in explaining movements in business fluctuations. The bulk of impulse responses given a real shock to the output gap may also be attributed to movements in nominal variables mainly as a result of inflationary movements. This economy specific parameter conveys the same message that Ragnar Frisch hypothesized in 1933 based on his 'rocking-horse theory'. The paper thus provides policy makers to identify key choice variables to use when reducing the impact of shocks in a given economy within a specified period of time.

JEL Classification: E31, E32, E52

Keywords: Business cycle; Vector autoregression; Impulse and propagation mechanisms; Hodrick-Prescott filter; Production function approach.

[a] Email address: themba.chirwa@mca-m.gov.mw, Phone (265) 888-511-848, Fax (265) 1-774-302

1.0 INTRODUCTION

Different schools of thought have presented varying theories regarding the causes of business fluctuations in a given time series. Real Business Cycle Theorists have argued that only real variables are important in defining the path of business cycles. New Keynesian Theorists, on the other hand, argue that nominal rigidities are the main source of real fluctuations. However, no school of thought has yet or recently considered a hybrid model that conveys the important role that both real and nominal variables play in defining the shape of a business cycle.

Real business cycle theorists argue that equilibrating movements in business cycles are driven by fluctuations in *natural endowments, technologies and tastes.* They further argue that these movements in real variables will behave in such a way that we will observe movements in a given series that *may look like business cycles* (Lucas, 1972, 1973; Tobin, 1980). New Keynesian theorists, on the other hand, have argued that nominal rigidities as a result of the presence of interdependencies cause staggered price-setting behavior (wage and price rigidities) in firms and these are largely the source of business fluctuations (Colander, 1992).

The proposal of the proponents of the real business cycle that only real shocks attribute to both impulse and propagation mechanisms on one hand and the existence of nominal rigidities as key drivers of business fluctuations in the New Keynesian School on the other is criticized in this paper. This paper introduces a *hybrid model* that aims at assessing the role of both real and nominal variables in explaining cyclical movements of business cycles. This deviates from what proponents of both the real business cycle and New Keynesian Schools have alluded to since Keynes' (1936) General Theory of Employment, Interest and Money and the New Keynesian approaches of nominal rigidities (Ball, Mankiw and Romer, 1988).

New economic events in the late 2000s as a result of the collapse of global financial markets have raised the question of what really causes fluctuations in real business cycles. A number of countries including the United States of America have resorted to the old Keynesian way of thinking; that of stabilizing the after-effects of economic shocks in order to curb the effects of yet another global depression. It has been widely believed that positive real shocks on factor productivity raises income of people through a multiplier-accelerator effect. However, the limitations in earlier explanations of the impact of real shocks on real business cycle theory and the impact of nominal rigidities as proposed by New Keynesians economics has highlighted the need for more empirical analysis.

The expansionary fiscal policy adopted by different countries affected by the global financial crisis is aimed at inducing public sector investment by providing a positive shock to real variables such as real GDP or a firm's output. The change of policy towards Keynesian stabilization policies from *laissez-faire* economics and indeed from the real business cycle point of view raises some important questions about the real causes of business cycles in certain macroeconomic variables.

The existence of speculation on the stock market has shifted the thinking to include not only the issue of regulation, but also how to identify the factors behind the realization of business cycles. It is known that the propagation of a financial time series after a company's annual profit announcement on the stock market is driven by other *factors*[1] rather than the initial profit announcement.

It is argued in this paper that though a real shock might cause an impulse in a series to shift from its equilibrium steady state as stipulated by real business cycle theorists, the propagation mechanism no longer results from movements in the real shock but rather equilibrating

[1] These factors include trading on the stock market, which is a purely demand-supply driven reaction, and people's beliefs that the industry will offer more profits in the future.

movements brought by both real and nominal variables. The approach herein argues that we ought to consider impacts from both real and nominal variables as elements that explain the cyclical movements in business fluctuations. The economy is still in resonance, just like Frisch's (1933) rocking-horse theory, and whatever hits the rocking horse and shifts it from its original position there will be some elements within the structure of the rocking-horse that maintains the momentum of the cradle. The frequency and magnitude of the resonance will depend on the type of wood, just like the types of institutions in a given economy.

This provides an alternative view on the behavior of economic time series and refutes the earlier claims by Real Business Cycle and New Keynesian theorists that business cycles are a result of only movements in either real variables or nominal rigidities, respectively. In a similar paper, Lucas (1987) argues that simply just focusing on real as opposed to monetary considerations is a mistake and it would be important to consider a *hybrid model* as a more dynamic and robust approach. The analysis in this paper, therefore, attests to Lucas' argument and brings new evidence which shows that a technological shock will only provide the first *impulse* and the random equilibrating movements or fluctuations in both real and nominal variables given a technological shock will *propagate* the impulse until it reaches its new equilibrium steady state value.

The structure of the paper has been organized in such a way that section 2 describes the literature on Real Business Cycle and New Keynesian theorists. Section 3 looks at the stylized fact of the proposition presented in this paper: *the role of both real and nominal variables in propagating the business cycle*. Section 4 outlines the methodology using the production function approach and the empirical results based on a Vector Autoregressive technique. Finally, section 5 presents the model summary and conclusions.

2.0 LITERATURE REVIEW

2.1 THE REAL BUSINESS CYCLE THEORY

Frisch (1933) postulated the separability between an impulse/shock from a propagation mechanism within a given time series and the latter usually comes from other sources rather than the shock variable. In addition, Keynes (1936) confirms the complexity of the trade cycle and states that it requires a great deal of complex analyses in order to fully understand the causes of business fluctuations. Though fluctuations in the propensity to consume, state of liquidity preference may play a role, Keynes believes that the essential character of the business cycle can be explained as a result of fluctuations in the marginal efficiency of capital (Keynes 1936). According to Keynes:

> "*The trade cycle is best regarded, I think, as being occasioned by a cyclical change in the marginal efficiency of capital, though complicated, and often aggravated by associated changes in the other significant short-period variables of the economic system.*"

The 1970s saw a transition from monetary to real theories of the business cycle stimulated by the two supply-side oil shocks of 1973 and 1979. This emphasized the importance of supply-side factors in explaining macroeconomic instability. The failure of the demand-oriented Keynesian models to account for rising and falling unemployment accompanied by changes in the inflation rate changed the perception and the way of thinking of macroeconomists in general (Snowdon, et al., 1994).

It is widely believed that supply-side shocks to the production function generate fluctuations in aggregate output and employment as rational economic agents respond to the altered structure of relative prices from their equilibrium values. With such a real shock, agents will change their labor supply and consumption decisions (Snowdon, et al., 1994). In support to these theories, several models were developed that were a dynamic set of difference equations. These models of the business cycle emphasized quantitative business cycles (Tinbergen, 1935), the marginal efficiency of capital (Keynes, 1936), the interaction of the multiplier-accelerator mechanism (Samuelson, 1939), and Koopman's (1949) structural equations through the System of Equations models.

As Kydland and Prescott (1991) notes, the quantitative behavior in the abovementioned classes of models depended on the parameter values of the included variables in the equation and was ill-suited since the *dynamics and uncertainty* were crucial elements in any model that attempted to study business cycles. These models also viewed fluctuations as being influenced by real aggregate demand mainly due to unstable investment expenditures. In particular, Frisch (1933) proposed that the main propagation mechanism was from capital and other related activities in capital construction. Monetary factors were being downgraded and supply-side impulses provided the constraints giving rise to business cycle turning points (Laidler, 1992).

The failure of neoclassicists to defend the policy ineffectiveness position gave further credence to the ideas of Frisch (1933) and Laidler (1992) that monetary policy could not be used to influence real variables once economic agents anticipated movements in short-period variables such as inflation. Though this provided the basis for assuming that real variables affect each other and business cycles existed as a result of movements in real variables constitute an assumption that is oversimplified.

There are two fundamental problems with the real business cycle theory. Firstly, real business cycle theorists argue that large random fluctuations are a result of changes or random movements in the rate of technological progress. This may be true as such random movements could depend on the type of technological advancement done by rational economic agents. However, the variability or volatility of the time series data cannot be explained by technological progress since a technology shock will not behave in this manner as the frequency of innovative ideas is a long-term phenomenon.

Secondly, judging models by way of simulation are questionable methodologies since they are prone to data mining and manipulation in order to fit the researcher's hypotheses. Several researchers have adopted this approach in assessing real business cycle hypotheses and even though they find results similar to movements in their intended time series the results obtained are usually questionable (see Kydland and Prescott, 1982 and Rebelo, 2005). As Uhlig (2005) notes, many of the identification schemes used by many researchers are usually a product of a specification search whereby researchers would look for 'reasonable' answers in order to support a theory.

Furthermore, the seminal work by Nelson and Plosser (1982) suggested that real shocks were far more important than monetary shocks in analyzing the path of aggregate output and could best be described as a random walk. But is this the case? Do or can real impulses also contribute to the propagation mechanism of time series or are they rather a result of another in-built mechanism within a given time series that we frequently or deliberately ignore as Economist?

2.2 THE NEW KEYNESIAN SCHOOL

Another school of thought developed in the 1980s that saw the emergence of New Keynesian economics. New Keynesian economics assume that fluctuations in output largely arise from *nominal rigidities* (Mankiw, 1985; Akerlof and Yellen, 1985; Blanchard and Kiyotaki, 1987; Ball and Romer, 1987; Colander, 1992; Mankiw and Reis, 2002). They argue that nominal shocks have real effects because nominal prices change infrequently. This is assumed since

New Keynesians believe that firms operate in an *imperfectly competitive* market where they are allowed to set their own product prices.

The New Keynesian argument is that the existence of macroeconomic externalities is the reason why one should expect price and wage rigidities. As Colander (1992) puts it, this depends on the level of interdependencies which may be expectational and hence create an economy with multiple equilibria. Mankiw (1985) argues that firms will take time to change their product prices due to the presence of menu costs – the cost of printing menus, catalogs, or replacing price tags. However, his argument has been criticized as sounding trivial and too small to cause impediments to nominal flexibility (Summers, 1988).

One interesting contribution is the *second-order private cost* and *first-order business cycle* modeling presented in Mankiw (1985) and Akerlof and Yellen (1985). They study imperfectly competitive economies and show that the cost of nominal rigidities to price setters can be much smaller than the macroeconomic effects. In their explanation they assume that a firm sets its price at the profit maximizing level but does not adjust after a fall in nominal money. Let's see how they outline their model: they assume that a firm follows a Taylor expansion model in setting the firm's price. Let $\Pi(P)$ denote the firm's profits as a function of its price, and let P be the firm's predetermined price and P^* the profit maximizing price. The firm's profit-loss function from not adjusting can be approximated as follows:

$$\Pi(P^*)-\Pi(P)\approx \pi'(P^*)(P^*-P)-\tfrac{1}{2}\pi''(P^*)(P^*-P)^2 \qquad (1)$$

They argue that since P^* is the profit maximizing price, then $\pi'(P^*)=0$ and the profit-loss from non-adjustment will largely emanate from the second order portion, i.e., $(P^*-P)^2$. As long as P is close to P^* the cost of price rigidity to the firm is small.

Blanchard and Kiyotaki (1987), on the other hand, argue that the presence of aggregate demand externalities provide an important interpretation of the result that Mankiw (1985) and Akerlof and Yellen (1985) presented. However, there are a few problems arising from Blanchard and Kiyotaki's (1987) modeling. In their equation, they assume that a firm's product demand depends on aggregate spending and on the firm's relative price, i.e.:

$$Y_i^D = \left(\frac{P_i}{P}\right)^{-\varepsilon} \left(\frac{M}{P}\right) \tag{2}$$

Blanchard and Kiyotaki (1987) assume rigidity in the firm's price (P_i) given a change in the nominal money supply (M). What is puzzling in this argument is the reason why a firm would not respond to market changes. The problem with New Keynesian modeling comes in due to highly abstract models being proposed such as the game theoretic models. Such modeling only allows the researcher to develop only theoretic conclusions that may not reflect reality. As a result of assuming such interdependencies, New Keynesians wrongly come to the conclusion that a macro economy may get stuck at less than full-employment equilibrium when there are not-perfectly flexible wages and prices (Colander, 1992).

There are several ironies that are not justified. In our argument, a firm has no incentive to reduce its product price unless it faces the following constraints:

a). There is a strong labor union that does not enable the firm to lay-off some workers when aggregate demand falls. It becomes costly for the firm as a result of long-term labor contracts to lay off some workers.

b). Firms believe that the reduction in nominal money is temporal hence no need for the firm to reduce its price if future expectations are such that nominal money supply will return to its equilibrium steady state.

However, the caveat in their arguments as presented in Mankiw (1985), Akerlof and Yellen (1985), Blanchard and Kiyotaki (1987) and Colander (1992) arises when they assume the existence of interdependencies as the main driver of nominal rigidities. So in a recession, the rigidity in the firm's price, for example, is assumed to lead to a decrease in first-order real aggregate demand and hence real output. However, this does not explain why firms would behave irrationally as not to follow market behavior. What this means is that they ignore the neutrality of money assumption and the existence of information lags as drivers of change. In the New Keynesian School, therefore, firms behave irrationally.

Secondly, the assumption of imperfect competition that sees output being at a suboptimal level all the time is rarely the case in a realistic world. This implies that prices will always be sub-optimally high and output sub-optimally low. In addition, the assumption of imperfect competition assumes that firms are always inefficient and would never charge to the socially acceptable or profit-maximizing price given that their predetermined price is above the profit-making price[2].

Thirdly, there is no reason why firms should not have an incentive to lower prices given a fall in nominal money and the presence of product substitutes. The contractionary monetary policy will lower aggregate demand and hence the demand for the firm's products given that its product price is above the perfectly competitive price. If the firm has excess capacity lying idle, it will be advantageous to hire some workers offering a lower wage and hence increase the firm's output and lower its price.

How is this possible? Consider a situation where an invention is made and a firm has acquired a patent. The sole right of production of such an invention lies in that firm.

[2] Notice that the assumption is that we are dealing with an imperfect market, the predetermined price will always be higher than the perfectly competitive equilibrium market price. This would only hold if that market is a pure natural monopoly. But as the current literature has shown, there is rarely a market in the world that is purely a monopoly.

However, new evidence has shown that copyright issues have been at the helm of controversies that replicas of the new invention are quickly becoming available on the world market. Piracies in the movie and cell phone industries are good examples of why imperfect markets are quickly becoming obsolete rendering the assumption of nominal rigidities (both for wages and prices) irrelevant. What this means is that the initial invention that is assumed to cause nominal rigidities by creating an artificial imperfectly competitive market is short lived. Functionally, the firm's price becomes a function of the piracy price which has a threat of capturing the market share of the original firm. In this scenario, the cost of price rigidity is small and the profit-loss adjustment from the second-order portion in equation (1) has a limiting distribution, i.e. $\lim P_i \xrightarrow{d} \overline{P}^*$.

The incentive for firms is, therefore, to devise ways of making the technology as cheaply as possible (either by price discriminating) through mass production and penetration in other markets before the pirated goods, which are usually of low quality, are fully spread onto the world market[3].

3.0 SOME STYLIZED FACTS ABOUT BUSINESS CYCLES

Having looked at the deficiencies of the two schools of thought the aim of the paper is, therefore, to introduce another form of modeling where we combine both real and nominal effects as contributing to business fluctuations. From the Real Business Cycle point of view, Nelson and Plosser (1982) have argued that macroeconomic models focusing on monetary disturbances as a source of purely transitory fluctuations may never be successful in explaining the large fraction of output variation. New Keynesians, on the other hand, have

[3] An example of such a scenario is in the cell phone industry where original and pirated blackberries are produced in the US and China. The influx of cheap Chinese blackberries have already filled markets in developing countries that render the price of the original blackberries three or four times expensive than the cheaper models.

provided different ways in which nominal rigidities play a part in affecting the equilibrium path of business cycles. We, therefore, provide an alternative view that the fluctuations should be seen as a result of propagation mechanisms derived from a combination of equilibrating movements generated by both real and nominal variables after an initial shock has been initialized.

3.1 Modeling Assumptions

This section provides a theoretical assessment of what happens in a business cycle. In order to introduce our line of thinking, several assumptions are made to define the modeling environment. These assumptions include the following:

a). Both firms and households operate in a *perfectly* or *near-perfect* competitive market. This implies that each firm is operating at its production possibility frontier without any barriers. Any innovation that creates disequilibrium is assumed to be absorbed in the perfectly competitive market by the reaction to the innovation from other firms.

b). *Expectations* play a major role in defining future prospects. Therefore, if firms or households expect output to rise, they will adjust their expectations accordingly. Secondly, if an innovation is on the market it is expected that others will copy that innovation and find ways of producing the original innovation cheaply. As a result there are no market externalities.

c). Inflation expectations are largely the determining factor to business fluctuations so that lower average changes to inflation will induce more output changes while higher average inflation changes will lower peoples' expectations and output.

d). Given rational expectations, there is no reason why firms should follow a staggered price setting behavior if the expectation given a monetary expansion/contraction will increase/reduce nominal money thereby increasing/reducing aggregate demand.

e). The key driving factor of short-run disequilibrium arises due to the presence of *information lags* which are always temporal unlike a macroeconomic externality that may be persistent. In this scenario, firms will adjust their prices differently depending on the first-hand information they have. The staggered prices envisaged may be a result of information lags feeding different firms and not due to market externalities.

3.1 General Equilibrium Analysis

3.1.1 Stepwise Case with no Monetary Disturbance

First we assume a scenario of no monetary disturbance. In this case a real innovation goes unopposed and is quickly transformed into the intended goods and services. Real business cycle theory is based largely on the intertemporal substitution of labor hypothesis by Lucas and Rapping (1969). According to this hypothesis, households will shift their labor supply over time being more willing to work when real wages are *temporarily* high and working fewer hours when they are *temporarily* low. Based on this view, real business cycle theorists argue that the hypothesis provides a powerful propagation mechanism.

Assuming that all things are held constant, a real shock through an increase in output would depict a stepwise equilibrating path since an increase in output would quickly be faced by a supporting increase in demand (see figure 1). However, other factors such as the level of income and price of the commodity play a role in defining the long-run equilibrium path of the real variable.

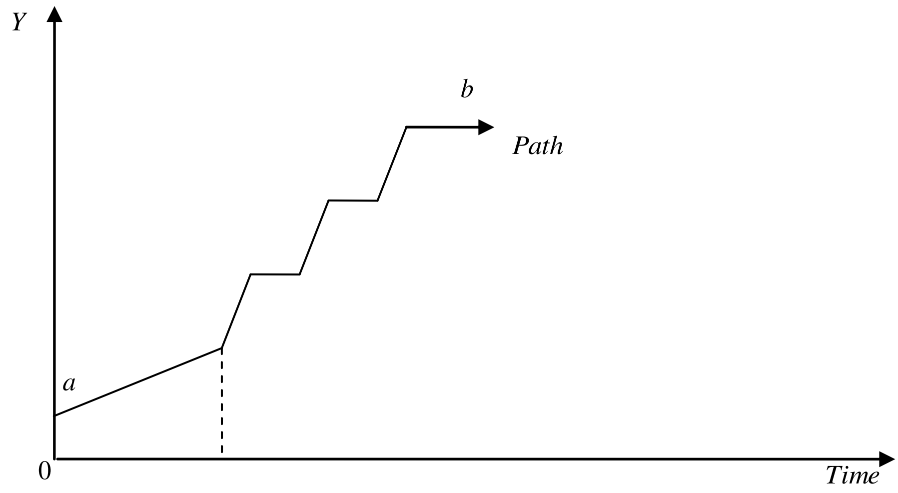


Figure 1: Time Path of Output in the 'Stepwise' Case with no Monetary Disturbance

3.1.2 Trend Reverting Case Given a Monetary Disturbance

In this scenario we assume that there is no real disturbance and that the economy is operating at its full capacity or on its production frontier. Figure 2 shows an equilibrium time path of output with an error correction mechanism given a monetary disturbance. Holding output constant with information symmetry, the equilibrating output path in the long-run will be given by the straight line (ab).

However, in the short-term due to information lags, a nominal shock will induce disequilibrium in demand and supply of goods and services by either creating an '*artificial*' supply or demand response[4]. Given the latter, this would induce traders to raise prices in response to high demand and vice-versa if it is a supply response. In any case, this creates or induces a monetary correction mechanism to correct the disturbance. In the long-run, however, following the expectations and policy ineffectiveness propositions, the illusionary effect of a monetary disturbance with full information will return to its original equilibrium path hence the '*trend reverting*' case scenario. This cycle will repeat itself once there is another monetary disturbance.

[4] If the technology is good it creates a high demand and if not the opposite is true where there is a higher supply response.

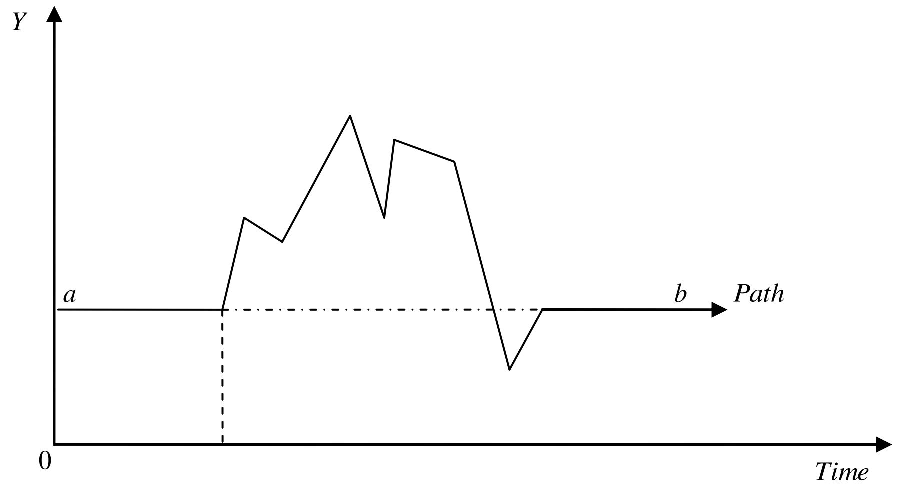


Figure 2: Time Path of Output in the 'Trend Reverting' Case given a Monetary Disturbance

Given a nominal shock in the short-run, the propagation mechanism may occur due to the presence of *information* lags. The information lags create significant spikes that will mimic business cycles until the real variable returns back to its equilibrating path. The volatility may therefore be explained by the unpredictable nature of whether the demand is temporal or permanent once there is a nominal shock from nominal money.

Stylized fact: given a nominal disturbance and the assumption of information lags in the short-run, disequilibrium in demand and supply is reverted back to its equilibrium steady state value through changes in the price level. Since nominal money is neutral, there are no changes in real output.

3.1.3 Real Shock with Trend Reverting Case

Figure 3 shows an equilibrium time path and its subsequent movements given a real shock and all relevant information. At point (a) the initial technological or real shock is assumed to revise the average level of output upwards permanently to a new equilibrium time path (path 2). In order to achieve this, monetary authorities also need to revise their inflation targets as well to conform to the new equilibrium path, say line (cd). Since the level of output at (b) is higher than the equilibrium price level, output will be reviewed downwards as the expectation is that the price level will rise and real wages will fall. In the short-run, monetary authorities do not know at what level the new equilibrium output will settle. As such their revision of inflation targets is random until the new equilibrium output is reached. This process will continue until point (c) is reached.

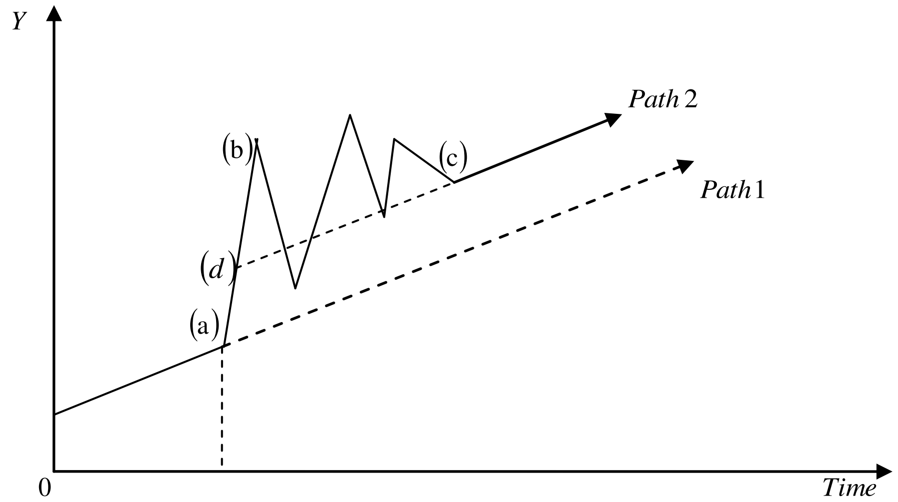


Figure 3: Time Path of Output with a Real Impulse and Nominal Propagation Mechanism

Furthermore, the reaction from other firms on the world market that copy the initial invention will cause the original price of invention to be lowered due to the influx of pirated materials. This will force prices on the world market to be revised significantly towards the socially optimum price until the equilibrium output is reached. In the short-run, therefore, lags in obtaining economic information will cause a '*trend reverting*' time path (from b to c) due to movements in the price level until a final equilibrium time path is reached at (c)[5]. In order to display how such movements are made, we now turn to the partial equilibrium analysis.

3.2 Partial Equilibrium Analysis - Short Run Scenario

One shortfall of New Keynesian Economics is that its questions cannot be answered by partial equilibrium analysis or in highly limited market frameworks (Colander, 1992). This

[5] Notice that at this stage, the key driver of changes in the price level originates from both the inflation parameter (price changes) and prices of firms.

poses a problem as the idea is to have theories that can be replicated through different modeling techniques.

Lucas and Rapping's (1969) intertemporal labor substitution hypothesis shows that the real impulse will originate from increases in the marginal productivity of labor which then increases real wage. However, with information symmetry, after the real shock has been initiated, further changes in the real wage variable will imply a change in the price level which is assumed to be flexible in the short-run.

The anticipated impulse from the real wage creates disequilibrium by creating an excess demand for goods and services. But what creates the cycle? We now turn to the theoretical argument of the effect of both real and nominal variables given a real shock. To understand how both real and nominal variables affect the equilibrium time path, figure 4 outlines the partial equilibrium analysis of a real shock.

From figure (4), the following are the stylized facts given a real impulse:

i) Notice that the assumption of nominal rigidities may apply in the very short-run supply curve SS'_m since the existence of a new patent will increase prices beyond the equilibrium price. The rigidity in this case is due to the lack of similar products on the market in which the existing firms holds an advantage. Since each firm is operating at its full capacity or near full capacity, the short-run supply curve will be vertical or near vertical. It is at this juncture that firms may face nominal rigidities as a result of the presence of information lags.

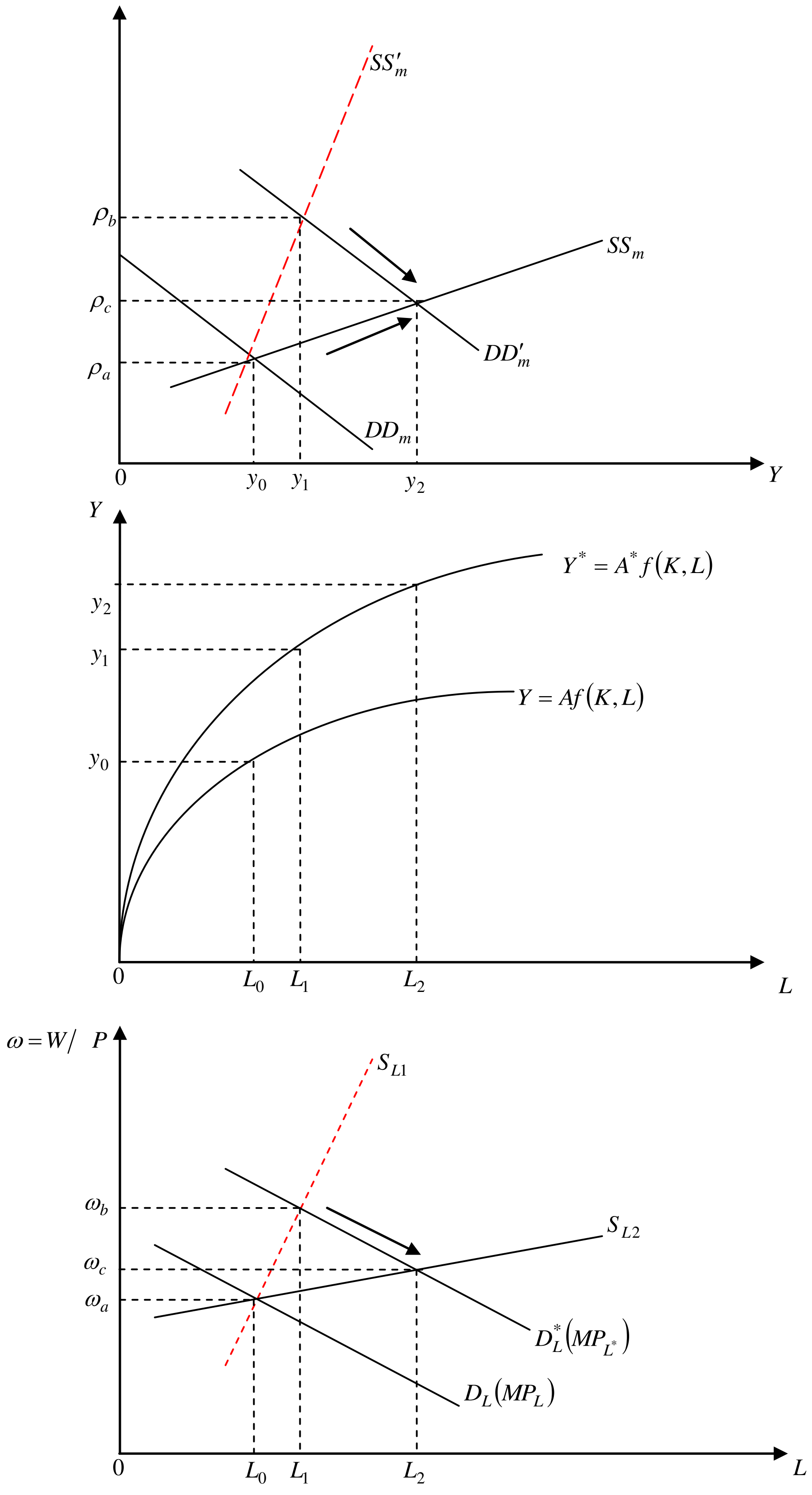


Figure 4: Partial Equilibrium Analysis given a Real Shock

ii) Given a technological shock that results in an improvement, say in labor productivity, in the short-run the real wage rate increases from ω_a to ω_b with an inelastic labor supply function. This shifts the production function to $Y^* = A^* F(K, L)$ and raise output to y_1 in the product market. The market price increases to p_b as a result of a firm holding a patent and creates disequilibrium in the goods market. The impulse or shock that led to the rise in the real wage creates a supply response in the short-run by raising output of the initial firm and the price level on the short run supply function, SS'_m.

iii) The high real wage rate offered in the labor market creates an incentive for other firms to produce the same product by copying the technology hence more demand for labor. As a result, the labor supply function (S_{L1}) becomes elastic in the long-run (S_{L2}) as well as the aggregate supply function. This forces the real wage rate structure to fall to ω_c but still increases the productivity of labor from $D_L(\mathrm{MP_L})$ to $D_L^*(\mathrm{MP_{L^*}})$ on the new production function $(Y^* = A^* F(K, L))$ which increases output further from y_1 to y_2.

iv) The decrease in the nominal price from p_b to p_c is made possible as economic agents face falling prices as a result of *market penetration* from other firms. Since the impulse shock is outweighed by the rise in the price level, expectations fall and the real wage rate falls but not below the initial real shock: $\omega_b > \omega_c > \omega_a = W/P_b > W/P_c > W/P_a$

v) In this case, the propagation mechanism is generated as a result of information lags due to economic agents constantly revising their expectations given a technological shock until new equilibrium levels are reached for the price level, capital and labor utilization and the level of unemployment. This is what will generate the spirals or cycles in a time series.

In the short run, therefore, the propagation is not unique due to the unpredicted nature of both real and nominal changes and will be at different magnitudes. This will cause cyclical behavior in the time series until the new equilibrium steady state level is attained. Thus, any real shock that shifts a given time series will revert to its new equilibrium steady state through interactions between short-period real and nominal variables in the goods market.

This conclusion emanates from the role that other firms play in copying the new technology on the market and the flexibility of the price level. This brings in a new stylized fact that we should expect short-run fluctuations to be caused by both real and nominal variables in business cycles while long-term movements to largely emanate from real shocks[6]. In the short-run, there are always unanticipated movements even when there is no information asymmetry which will result from decision lags and demand-supply interactions.

4.0 METHODOLOGY

4.1 Introduction

We have shown theoretically that at the helm of random movements in business cycles are responses mainly driven by both real and nominal variables. The question, therefore, is whether this can be verified empirically using secondary data. In this section we develop a model that will aid in explaining this phenomenon.

Mikhail (2004) provides an up-to-date modeling where he introduces a parameter that represents the role of economic institutions, financial integration and regulation as drivers of business cycles. However, his assessment is based on simulations which are sensitive to the user's subjective judgment and *transversality conditions* for the latent variable employed are not well expounded in the model. In addition, following Frisch's (1933) rocking horse theory, the absorptive capacities represented by institutions often play a big role in influencing the shape of the business cycle. However, Mikhail (2004) does not explain whether these

[6] This assumption is based on the fact that innovations will take time to be developed while responses to such innovations will depend on how quickly the market will copy the new innovation.

variables create an impulse or act as a propagation mechanism in the standard real business cycle model. His modeling, therefore, raises the following problems.

Firstly, the introduction of the role of institutions by introducing a latent variable in his model downplays the '*decision-making*' lag that is typical in any institution. The lag will usually create a lapse which is not synonymous with the shape of business cycles. The bureaucratic nature of institutions means that it will take time before a law or regulation is passed that would influence movements or propagations after a real shock. Quantitatively, it would be difficult to assume continuity of a given equation through dynamic optimization. Hence, the trade-off between depth and duration may be caused by other factors that are mainly superior to the role that institutions play.

Secondly, Mikhail (2004) assumes that the absorptive capacity through the latent variable is multiplicative with the technology factor which presents its own problem of depicting which of the parameters drive the business cycle. Taking all these into account, this paper presents a different methodology of using *additive quantitative parameters* that will show where the propagation is being developed and at what magnitude considering both real and nominal variables.

4.2 Model Specification Using the Production Function Approach

We slightly revise the standard real business cycle model that uses the production function approach to introduce a nominal variable into the model. We also re-modify Mikhail's (2004) model and assume that the absorptive parameter is '*additive and time dependent*' as opposed to the multiplicative structure presented in his paper. We also assume that the closest nominal variable that would influence a propagation in a given time series is inflation (price changes). At the micro level, the representative household will therefore solve the following problem:

$$\max_{(C_t, l_t, K_{t+1})_{t=0}^{\infty}} E_t \left\{ \sum_{t=0}^{\infty} \beta^t \left(\log C_t - \gamma L_t \right) \right\} \qquad (3)$$

This is subject to the following:

Neoclassical Production Function: $Y_t = A_t K_t^{\alpha} L_t^{1-\alpha}$ (4)

Capital law of motion: $K_{t+1} = (1 - \delta_K) K_t + i_t \leq 0;$ $\overline{K} > 0$ (5)

Resource Constraint: $C_t + i_t \leq Y_t$ (6)

Time Constraint: $l_t + L_t \leq 1$ (7)

The parameters C_t, i_t, L_t, l_t, K_t and Y_t refer to aggregate consumption, investment, total working hours, leisure hours, capital and output, respectively. The term E_t is the expectation operator while A_t denotes the technology shock. The term β is the subjective time discount factor where $\beta \in (0,1)$ which is defined as $\beta \equiv 1/(1+\rho)$, the variable ρ is the rate of time preference. The parameters α and δ_k are the capital share in income and the depreciation rate for capital, respectively. The constraints given in equations (6) and (7) rule out continuous accumulation of wealth by rational economic agents in which case we assume that they behave optimally.

In equation (4) we assume that each factor of production has positive but diminishing marginal physical productivity as depicted in figure 4. However, given a technological shock, the productivity parameter will also shift but still retain the property of diminishing returns. It has been argued that in order to assure the existence of a competitive equilibrium, the production function must exhibit constant returns to scale (Romer, 1986). We relax this assumption to account for other structures that may arise due to rigidities and total returns to scale may either be increasing or decreasing depending on whether the spillover from a given technological shock is positive or negative.

The technological shock in this case is assumed to be driven by the parameter/variable A_t and at this juncture we introduce a parameter assumed to be the main driver of business cycles in the technological shock equation, the *inflation rate*. The evolution of the technological shock, therefore, may be represented as follows:

$$A_{t+1} = e^{\pi_t} A_t^{\psi} \overline{A}^{(1-\psi)} \tag{8a}$$

The inflation parameter enters into the equation as an exponential function. In logarithmic terms:

$$\ln A_{t+1} = \pi_t + \omega \ln A_t + (1-\omega)\overline{A} \tag{8b}$$

The parameter has been introduced based on *Euler's theorem* which states that given an optimal path, no gain can be achieved by a slight deviation from an optimal path in the short-run (see Turnovsky, 1999). In this process, a continuous time series returns to its equilibrium time path once subjected to a shock. With such a rule, since business cycles are fluctuations around an optimal path, the assumption of a technological shock influencing business cycles cannot hold since a technological shock has no tendency to return to its original equilibrium time path once initiated as shown in figure 3. Therefore, there must be other variables that influence such propagating movements in business cycles. Given the way time series behave as we will see when we invoke the HP filter, optimal time paths are rarely fixed and as a result there could be many paths satisfying the Euler optimizing equation.

From equations (8a) and (8b), given the possibility of a time series having more than one optimal time path, it is important that *transversality conditions* are invoked for the role of the inflation parameter to hold. Transversality conditions refer to optimal conditions that are used along with Euler equations and characterize the optimal paths of dynamic economic models. The transversality condition for the inflation parameter introduced, therefore, should be seen to converge towards its equilibrium steady state value.

In this case, the endogenous economy-specific parameter assumed in this paper mainly responsible for variable fluctuations is represented by the inflation rate and this parameter is assumed to define the magnitude and depth of the propagation. The inclusion of the parameter is assumed to be additive once transformed into logarithmic terms as given in equation (8b). Note that the inflation parameter only affects the evolution of the technological shock and does not directly enter the production function expressed in equation (4).

To complete the structure of our modeling, we assume that the labor function will be defined by total working hours which are assumed to be generated as a function of the total labor force (N_t) and the average number of working hours per person employed (H_t) multiplied by the national rate of employment in a given period $(1-u_t)$[7].

Total Working Hours: $$L_t = (1-u_t)N_t H_t \tag{9}$$

The production function model given by equation (4) can be written as follows:

$$Y_t = e^{\pi_t} A_t^{\psi} \overline{A}^{(1-\psi)} K_t^{\alpha} \left[(1-u_t)N_t H_t\right]^{(1-\alpha)} \tag{10}$$

Notice that, unlike the standard business cycle modeling using the production function approach, total factor productivity given in equation (8b) is an endogenous function of a

[7] In this case u_t is defined as the national unemployment rate in a given period of time.

technological parameter $(\psi \geq 0)$. Also note that in the absence of any technological shocks $(\psi = 0)$, the periodic inflation rate is assumed to define the shape of the business cycle given a base technology $(\overline{A})$ maintaining the original equilibrium path. In this case the optimal time path for output in a given period will be defined by the constant $(\overline{A})$. If $\psi = 1,$ then the full technological shock may be driven by the new innovation in a given period that shifts the original equilibrium time path to a new level. As such, the variable becomes a shift factor in the long-run equilibrium output. The inflation rate of that period is assumed to control any demand-supply movements that may cause the new equilibrium not to be attained.

In order to assess the impact of these variables on the business cycle, we define the business cycle based on the conventional definition. A time series can be defined as being generated by two components: the first being the *growth component* and then the *cyclical component*. It is the latter that defines the business cycle and detrending the series is the appropriate methodology of collecting the cyclical component. However, since it is unreasonable to assume that growth is constant over time in a given time series, we use the Hodrick-Prescott (1997) filter to obtain residuals from a time series representing business cycles. The Hodrick-Prescott (or HP) filter is a smoothing method used to obtain time-dependent smooth estimates of the long-term trend component of a given time series. Taking logs of equation (10), we obtain the following equation:

$$Y_t = \pi_t + \psi \ln A_t + (1-\psi)\ln \overline{A} + \alpha \ln K_t + (1-\alpha)[\ln N_t + \ln H_t + \ln(1-u_t)] \qquad (11a)$$

Using the production function approach, we can define the *output gap* as the difference of a time series from its given trend state (or mean). In this case the trend value is given by the HP filter in log terms. The trend or potential output level can be defined as the average output for all given variables in the production function. Hence, we take the mean values of equation (11a) as follows:

$$\bar{Y}_t = \bar{\pi}_t + \psi \ln \bar{A}_t + (1-\psi)\ln \bar{\bar{A}} + \alpha \ln \bar{K}_t + (1-\alpha)\left[\ln \bar{N}_t + \ln \bar{H}_t + \ln(1-\bar{u}_t)\right] \tag{11b}$$

Assuming lower case letters to represent log of a variable, the output gap, therefore, is given as follows:

$$y_t - \bar{y}_t = \pi_t - \bar{\pi}_t + \alpha(k_t - \bar{k}_t) + (1-\alpha)\left[(n_t - \bar{n}_t) - (u_t - \bar{u}_t)\right] \tag{12}$$

Note that in equation (12) given an equilibrium time path, it is reasonable to assume that total factor productivity $\left[\omega(a_t - \bar{a}_t) + (1-\omega)(\bar{a} - \bar{\bar{a}}) = 0\right]$ and the average working hours per person employed $(h_t - \bar{h}_t = 0)$ are fully utilized in a given period and are used to maximize the new equilibrium time path[8]. One interesting feature arises from the cyclical component of the evolution of the technological shock in a given period. Assuming that this is represented by the marginal efficiencies of capital and/or labor, any technological improvement given rational expectations is assumed to be fully employed in a given period rendering the deviations from its periodic mean to be zero[9]. Hence, the technological component does not influence in any way propagations in business fluctuations. It can also be deciphered at this juncture that a technological shock will only initiate an impulse in a given period but will not drive or propagate the business cycle in a given time series.

---

[8] This conditionality means that nothing should be saved in the last period unless it is costless to do so. That is, an economic agent will not carry forward any working hours lost or new invention to the next period.

[9] The marginal productivity of capital is the annual percentage return on the last additional unit of capital.. It may represent the market rate of interest at which the investment becomes viable. Total factor productivity, which is a combination of all factor productivities, is represented by the function $(a_t - a_{t-1})$. If the relevant authorities target this rate accordingly, then we should expect that the market rate of interest in a given period should not deviate from its equilibrium rate, i.e., $(a_t - \bar{a}_t = 0)$.

We, therefore, assume that an output cycle can be explained by movements in the inflation cycle, gaps in fully utilizing existing capital, gaps in utilizing total working hours, and the unemployment cycle. As such, the elements which will remain are, therefore, deviations from *choice variables* in targeted inflation $(\pi_t - \bar{\pi}_t)$, physical capital $(k_t - \bar{k}_t)$, physical labor $(n_t - \bar{n}_t)$ and the unemployment rate $(u_t - \bar{u}_t)$ from their equilibrium values. These may be regarded as the real and nominal *policy-components* of a production function driving business fluctuations.

In this case both real and nominal variables play an important role in defining the output gap thereby concurring with Lucas (1987) that we should consider a *hybrid model* when evaluating business fluctuations. It also creates *policy variables* that ought to be considered when dealing with recessions or booms and explains why usually there is an output gap in a given time series as the gaps from inflation, physical capital, physical labor and unemployment are rarely at their equilibrium level[10]. By introducing a nominal variable in the production function enables us to explain the full dynamic properties of the business cycle and attest to the role that both real and nominal variables play in defining the path of business cycles.

Furthermore, as seen from equation (12) and attesting to Frisch's (1933) hypothesis, we can easily separate an impulse shock from a propagation mechanism. A technological shock from either a rise in the marginal efficiency of capital or labor is regarded as an impulse parameter as they are time-specific and not time dependent. These parameters do not enter the propagation mechanism equation and therefore when running equation (12) we assume that the shock has already been initiated.

[10] As previously noted, this is made possible by firms who copy the initial invention and supply products on the world market at a reduced price.

4.3 Dynamic Optimality Conditions

It is important at this juncture to consider the stability of equation (12). Since the driving factor is the overall output variable in the sense that rational economic agents will opt to maximize output in a given period, we refer each period's output as the *state variable*. The role of economic agents is to ensure that they choose the appropriate framework to achieve each new steady state output value. In this case we assume that the policy instruments are the *choice variables* given on the right hand side of the equation.

Since the analysis is on a finite dataset, we will be interested in the dynamic properties of the choice variables and in particular, the inflation parameter in the selected time period from $(0-T)$ inclusive, where T is an integer $(T \in \mathrm{N})$. We also assume that the initial (y_0) output value is given and the endpoint (y_{T+1}) output value is a free-endpoint control problem. In this case, the optimization condition can be written as a function of the given variables in equation (12).

$$y_{t+1} - y_t = g_t(\pi_t, k_t, n_t, u_t, y_t) \qquad (13)$$

The role of the rational economic agent is, therefore, to maximize *choice variables* given on the right hand side of equation (13) and each year's policy will be to choose the appropriate levels of the choice variables (π_t, k_t, n_t, u_t) for each new desired equilibrium steady state to be attained given a technological shock. Since there are rewards in each period for reaching the desired state of output, the rational economic agent's problem is to maximize the sum of all rewards in a given period through the following function:

$$\max_{(\pi_t, k_t, n_t, u_t, y_t)_{t=0}^{\infty}} \sum_{t=0}^{T} f_t(\pi_t, k_t, n_t, u_t, y_t) \qquad (14a)$$

Subject to: $$y_{t+1} - y_t = g_t(\pi_t, k_t, n_t, u_t, y_t) \tag{14b}$$

Since the assumption of the agent maximizing the simple sum of single-period rewards may be more general, discounting of the maximization function may be appropriate due to the time-dependence nature of the given function. The application of Lagrange's method of undetermined multipliers is inevitable given equation (13). This can be represented as follows:

$$\begin{aligned} &L(\pi_0,\ldots,\pi_T, k_0,\ldots,k_T, n_0,\ldots,n_T, u_0,\ldots,u_T, y_0,\ldots,y_T, \lambda_0,\ldots,\lambda_T) \\ &\quad = \sum_{t=0}^{T} \beta^t \{f_t(\pi_t, k_t, n_t, u_t, y_t) - \lambda[y_{t+1} - y_t - g_t(\pi_t, k_t, n_t, u_t, y_t)]\} \end{aligned} \tag{15}$$

The Euler equations for optimality, therefore, require that the following first-order conditions are obtained:

$$\begin{gathered} \frac{\partial L}{\partial \pi_t} = 0; \frac{\partial L}{\partial k_t} = 0; \frac{\partial L}{\partial n_t} = 0; \frac{\partial L}{\partial u_t} = 0; \frac{\partial L}{\partial y_t} = 0; \\ \text{for all } (t = 0,1,\ldots,T) \end{gathered} \tag{16}$$

This assumption is important in our model given deviations being explained by the choice variables in equation (12). *Information lags* in a given period are seen as temporary (short-run deviations) and policy choices in the assumed explanatory choice-variables will determine the short-run movements. For comparison using the *Hamiltonian* expression, for each $(t = 0,1,\ldots,T)$:

$$H_t(\pi_t, k_t, n_t, u_t, y_t, \lambda_t) = f_t(\pi_t, k_t, n_t, u_t, y_t) + \lambda_t g_t(\pi_t, k_t, n_t, u_t, y_t) \tag{17a}$$

It follows from equation (17a) that the Lagrange multiplier over the period can be expressed as:

$$L=\sum_{t=0}^{T}H_t\left(\pi_t,k_t,n_t,u_t,y_t,\lambda_t\right)+\sum_{t=0}^{T}\lambda_t y_t-\sum_{t=0}^{T}\lambda_t y_{t+1} \tag{17b}$$

Since in this case the next period state variable can be written as:

$$\sum_{t=0}^{T}\lambda_t y_{t+1}=\lambda_0 y_1+\ldots+\lambda_{T-1}y_T+\lambda_T y_{T+1}=\sum_{t=0}^{T}\left(\lambda_{t-1}y_t\right)+\lambda_T y_{T+1} \tag{17c}$$

Then we can write equation (17b) as follows:

$$L=\left\{H_0\left(\pi_0,k_0,n_0,u_0,y_0,\lambda_0\right)+\lambda_0 y_0\right\}+\sum_{t=0}^{T}\left\{H_t\left(\pi_t,k_t,n_t,u_t,y_t,\lambda_t\right)+\left(\lambda_t-\lambda_{t-1}\right)y_t\right\}-\lambda_T y_{T+1} \tag{18}$$

We can thus write the Euler equations for the maximizing Hamiltonian function as follows:

$$\frac{\partial H}{\partial \pi_t}=0;\ \frac{\partial H}{\partial k_t}=0;\ \frac{\partial H}{\partial n_t}=0;\ \frac{\partial H}{\partial u_t}=0;\quad \text{for all }\left(t=0,1,\ldots,T\right) \tag{19a}$$

$$\frac{\partial H}{\partial y_t}=\lambda_{t-1}-\lambda_t\qquad \text{for all }\left(t=0,1,\ldots,T\right) \tag{19b}$$

Since we assume that the endpoint condition is variable based on the level of technological shocks, the optimal condition may be represented as follows:

$$\frac{\partial H}{\partial y_{T+1}}=0\qquad \text{for all }\left(t=0,1,\ldots,T\right) \tag{19c}$$

From equation (18), since the Lagrange is linear in y_{T+1} then the necessary condition for our equation is that $\lambda_T=0$. This is the *transversality condition* for the unknown free-endpoint problem – that is, the rational economic agent attains the desired equilibrium steady state output given a technological shock. Euler equations for π_t,k_t,n_t,u_t in Equation (19a) are the *control conditions* and the Lagrange multiplier λ_t, is our *costate variable* and it follows that equation (19b) is the *costate equation*. Through dynamic optimization theory, therefore, we have shown that the state equation given in equations (12) and (13) are optimal equations as expressed by the *Hamiltonian expression* as follows:

$$
\begin{aligned}
\frac{\partial H}{\partial \lambda_t} &= y_{t-1} - y_t \\
&= y_t - \bar{y}_t \\
&\text{for all } (t = 0,1,\ldots,T)
\end{aligned}
\qquad (20)
$$

Note the last expression in equation (20) where we assume that the conformity of equations (12) and (13) to the Hamiltonian expression can be expressed as deviations from the last period's forecast. Therefore, the best estimate on the equilibrium trend value is the last period's mean state value of the output level which will always be given. Also note that from equation (12) we assume a positive relationship between inflation, capital and output gaps. The signs for total working hours and the unemployment gap will depend on the magnitude of the parameter (α).

4.4 VAR Representation of the Production Function

We have presented the optimality conditions for the standard business cycle model that enables the convergence towards the equilibrium steady state output path. We now test our model to determine what roles real and nominal variables play in driving and shaping business cycles. A closer look at equation (12) shows that we can regard every variable entering into that equation as endogenous as each variable can be generated separately. For example, total labor force could be a function of skills and education levels of the existing labor force. We can therefore run equation (12) using Vector Autoregression (VAR) modeling. Cointegration tests are carried in order to prove this point.

4.4.1 Data Sources and Manipulation

The data was obtained from the World Economic Outlook database (2009) for a period 1980-2010[11] and include real GDP, gross capital formation, inflation, total labor force, working hours per person[12] employed and the unemployment rate. The information collected is based on four countries, namely: United States of America (USA), United Kingdom (UK), Canada, and Germany[13]. We define the parameters as follows: real GDP is expressed as gross domestic product (GDP) at constant market prices; the inflation rate is a harmonized index of consumer prices on an annual basis; the cyclical component of the capital gap is given by the HP filter generated by the gross capital formation, which is defined as a percentage of real GDP and represents the time series defining the capital law of motion on an annual basis; the labor gap is defined by equation (9) and is used to obtain the cyclical component based on the HP filter; and finally the country-specific unemployment rate is used to define the HP filter of the unemployment gap. Real GDP, capital and labor are transformed into natural logarithms except for inflation and the unemployment rate.

The aim is to assess *impulse responses* and *variance decompositions* of the variables used. As Stock and Watson (2001) notes, impulse responses in VARs will trace the effect of a one-time shock to one of the innovations on current and future values of the endogenous variables assuming that the error will return to its equilibrium steady state value in subsequent periods. It is further used to investigate the dynamic interactions between the endogenous variables in a given VAR. Variance decompositions, on the other hand, will separate the variation in an endogenous variable into the component shocks to the VAR and will provide information about the relative importance of each random innovation affecting the variables of the VAR (Pfaff and Taunus, 2006).

[11] The World Economic Database has projected data for 2009 and 2010.
[12] The average hours worked for each country is assumed by the author.
[13] The selection of countries was based on data availability from the World Economic Outlook database.

4.5 Diagnostic Testing

Engle and Granger (1987) pointed out that if given a number of non-stationary series, any linear combination of these variables may be stationary. If such combinations exist then the series are said to be cointegrated. As such we can develop long-run equilibrium relationships among the variables that will enable the system of variables converge to their equilibrium steady state values once a shock has been initiated. In line with the assumptions presented, variables in equation (12) ought to be tested for cointegrating relationships. This will form the basis for estimating Vector Error Correction models (VECM)[14].

We employ the methodology developed by Johansen and Juselius (1990) and Johansen (1991, 1995) to test for cointegration. The cointegration test is performed for equation (12) variables in the four countries being tested. The test assumes no deterministic trends in each of the variables and the results are given in table 1 below:

Table 1: Unrestricted Cointegrating Tests

Country	No. of Cointegrating Equations (CEs)	Probability
USA	At most 3 (or 2 CEs)	0.1125
UK	At most 2 (or 1 CE)	0.1263
Canada	At most 4 (or 3 CEs)	0.1521
Germany	At most 4 (or 3 CEs)	0.0947

The results in table 1 show that it is appropriate for us to estimate a VAR for equation (12) in all four countries.

We further test for serial correlation in our four-country equations. We use an autocorrelation LM test that reports a multivariate LM test statistic to test for residual serial correlation up to a specified order of two (2). The LM statistic is assumed to be asymptotically distributed as a

[14] We have deliberately ignored the description of how the VAR is generated and left the reader to consult the relevant books on how a VAR or VECM is structured. What we are interested in this section is to provide the model results subject to diagnostic tests.

chi-squared (χ^2) distribution with k^2 degrees of freedom. If there is evidence of any serially correlated errors then we may consider employing structural VAR $(SVAR)$ modeling to obtain non-recursive orthogonal transformations of the error terms using structural decompositions.

Blanchard and Quah (1989) argue that certain macroeconomic variables may be affected by more than one shock and by structurally decomposing the variables may lead to more information being exploited if we consider other variables. However, Pfaff and Taunus (2006) have also argued that the structural coefficients obtained may not differ from their reduced form counterparts once the errors are found to be orthonormal. If this is the case, then the SVAR model will provide the same coefficient estimates than using an unrestricted VAR employed in this paper.

The multivariate autocorrelation LM test results for the unrestricted VAR estimated for each of the four countries show the following results:

Table 2: VAR Residual Serial Correlation LM-Test Statistics

Country VAR	Lags	LM-Statistic	Probability
USA	1	28.4354	0.2882
	2	28.4013	0.2897
UK	1	15.5870	0.9266
	2	18.6654	0.8129
Canada	1	26.8766	0.3621
	2	36.4983	0.0644
Germany	1	28.7592	0.2741
	2	20.9914	0.6931

Based on the null hypothesis of no serial correlation of order 2 at the 5% significance level, the results in all countries show that we can reject the null hypothesis and assume that the error terms are orthonormal. Thus, we can still employ the unrestricted VAR to obtain our results.

4.6 Empirical Results

VAR equations were estimated using equation (12) for the four countries using the following order of variables: real GDP cycle, inflation cycle, capital cycle, labor cycle and unemployment rate cycle. Since in this paper we are interested in the shapes and magnitudes on the impact of both real and nominal variables on output fluctuations, we will only present impulse responses and variance decompositions for real GDP shocks on the choice variables. Based on our earlier assumption, we assume that both real and nominal fluctuations play an important role in explaining movements in output fluctuations. Annexes (1) through (3) shows the accumulated and non-accumulated impulse responses and variance decompositions for the variables used in equation (12).

The evidence provided by accumulated impulse responses or propagations given a shock on real GDP in annex (1) show that the inflation gap has the highest and immediate response in all the four countries. Labor, physical capital and unemployment rate gaps tend to have lagged responses usually after one or two periods. The evidence also suggests that an inflationary impulse response is persistent usually over four periods. This lends support to the argument of why it takes time for either a recession or a boom to return to its equilibrium steady state value as inflation targets by monetary authorities are constantly being revised in order to reduce the output gap of the new equilibrium path.

Also notice that when inflation changes are large enough (more than 1% change), peoples' expectations are revised as they expect that larger inflation changes will lead to reductions in the output gap towards its equilibrium steady state value. At this point, firms and households will factor this signal extraction as an aspect used to revise their output expectations downward. Capital and labor responses show erratic behavior and will usually die down more quickly compared to an inflationary response. However, they have a significant contribution toward the reduction of the output gap to its equilibrium steady state value.

Finally, using variance decompositions (annex 3), it is clear that convergence in real GDP given a shock is usually driven by inflation (a nominal variable) and the labor gap (a real variable) when returning to the output equilibrium steady state value. This evidence is supported by variations in all four countries.

5.0 SUMMARY AND CONCLUSIONS

The paper has assessed the important role that real and nominal variables play in explaining business fluctuations and has diverted from the norm as proposed by Real Business Cycle and New Keynesians theorists of separating the impacts. The paper shows that the combined propagation mechanisms brought by both real and nominal variables cannot be treated or assessed separately and they have a role to play in controlling the output gap. As such, knowledge of movements in inflation, physical capital, physical labor and unemployment rate are a good starting point in controlling business cycles. In addition, a diversion from each variable's equilibrium path is a better approach than using variables in their levels as previously investigated by different researchers.

We have employed the production function approach and Vector Autoregressive (VAR) techniques to bring out this conclusion. We find that holding other factors constant, the deviation of real variables (physical capital, physical labor and partly from the unemployment gap) from their equilibrium values will be used to reach the final resting path of the technological shock as rational economic agents are still revising their production functions. Nominal changes, on the other hand, will be used largely to correct the output gap and the level of aggregate demand.

The results also entails that stochastic variations observed in business cycles of output series should be caused by both real and nominal movements from their equilibrium path, which in the short-run create disequilibria seen as business cycles. This is also evidenced by the relative importance of inflation, capital and labor shown by variance decompositions in annex (3). Usually gaps in capital and labor will react after two (2) or three (3) periods given an initial shock. This can be explained by the response from other firms who have copied the technology and are able to increase output using the existing physical capital or labor depicted by their cycles.

There are various reasons why both real and nominal variables can provide a basis for propagating business cycles. Firstly, as seen in section 3 and 4 of this paper, the technological shock will create the initial impulse that has an impact on aggregate supply. The new innovation will induce changes in real variables such as physical capital and total hours worked. One of the plausible reasons that have been given in this paper is the role that other firms play in copying the new innovation. The influx of the cheaper products on the market will cause the original firm's monopolistic price to be reduced towards the profit-maximizing price in a perfectly competitive world. The time it takes for firms to make these decisions will be reflected by business cycles.

Since output has been revised upwards, the Central Bank will revise its inflation targets upwards as well in order to control the rising aggregate demand thereby reducing the inflation gap. On the other hand, the changes in the price level will alter the structure of real variables such as the real wage and thereby induce movements in the level of capital and labor employed by firms.

Secondly, we have shown that the revision of the inflation target by the Central Bank is persistent and would last relatively over a long period. Since the Central Bank does not usually know when the new output equilibrium will rest, they keep on revising the inflation target until they reach a level where they feel that output has stabilized and there is no excess demand or supply in the market. Usually such '*guess work*' may slow down economic activity and cause a recession in the absence of a real shock or nominal rigidities if not properly forecasted.

Disequilibrium caused by a real technological shock on output will, therefore, create an initial impulse and will return to its new equilibrium steady state with assistance mainly from propagations initiated by real and nominal variables from their equilibrium steady state values. The shape of the cycle will be driven mostly by the impulse from a real shock, just like when one hits and moves a rocking chair from its initial position and the resonance is left to the momentum within the wood.

One question still remains: is monetary policy ineffective in influencing output fluctuations? Permanent revisions on the inflation target by the Central Bank through changes in nominal money supply are bound to have permanent impacts on real variables such as the real wage and real output. Going back to the real wage variable $(\omega = W/P)$, a temporary change in the price level will create a temporary change in the real wage which has a tendency to return to its equilibrium steady state value, hence the policy ineffectiveness proposition. However, if the change is permanent then individual expectations will also be revised either upwards or downwards permanently depending on direction of change. In the process output in the goods market will also be permanently revised accordingly. In this case, monetary policy may become effective in influencing real variables in the long-run.

Finally, the study provides room for further research as it has been assessed only in highly developed countries that fit the assumptions portrayed in this paper. Future studies may be replicated in developing countries to see whether the assumptions hold. Lack of quantitative data in developing countries has restrained the extension of the analysis.

6.0 BIBLIOGRAPHY

Akerlof, G. A. and J. L. Yellen (1985), 'A Near-Rational Model of the Business Cycle with Wage and Price Inertia', *The Quarterly Journal of Economics*, 100, 823-838

Ball, L. and D. Romer (1987), 'Are Prices too Sticky?' Working Paper 2171, *NBER*, February

Ball, L., N. G. Mankiw and D. Romer (1988), *The New Keynesian Economics and the Output-Inflation Trade Off*, available at www.econturk.org/Turkisheconomy/9506.pdf

Blanchard, O. J. and N. Kiyotaki (1987), 'Monopolistic Competition and the Effects of Aggregate Demand', *The American Economic Review*, 77 (4), 647-666, September

Blanchard, O. J. and D. Quah (1989), 'The Dynamic Effects of Aggregate Demand and Supply Disturbances', *American Economic Review*, 79 (4), 655-673, September

Colander, D. (1992), '*New Keynesian Economics in Perspective*', available at www.community.middlebury.edu/~colander/articles/New%20Keynesian%20Ec%20in%20Persp.pdf

Engle, R. F. and C. W. J. Granger (1987), 'Cointegration and Error Correction: Representation, Estimation, and Testing', *Econometrica*, 55, 251-276

Frisch, R. (1933), 'Propagation and Impulse Problems in Dynamic Economics', in *Essays in Honor of Gustav Cassel*, London: Allen and Unwin

Hicks, J. R. (1950), *A Contribution to the Theory of the Trade Cycle*, Oxford: Oxford University Press

Hodrick, R. J. and E. C. Prescott (1997), 'Post-war U. S. Business Cycles: An Empirical Investigation', *Journal of Money, Credit and Banking*, 29, 1-16

Johansen, S. and K. Juselius (1990), 'Maximum Likelihood Estimation and Inferences on Cointegration – with applications to the demand for money', *Oxford Bulleting of Economics and Statistics*, 52, 169-210

Johansen, S. (1991), 'Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models', *Econometrica*, 59, 1551-1580

Johansen, S. (1995), *Likelihood-based Inference in Cointegrated Vector Autoregressive Models*, Oxford: Oxford University Press

Keynes, J. M. (1936), *The General Theory of Employment, Interest and Money*, London: Macmillan

Kydland, F. E. and E. C. Prescott (1982), 'Time to Build and Aggregate Fluctuations', *Econometrica*, November

Kydland, F. E. and E. C. Prescott (1991), 'The Econometrics of the General Equilibrium Approach to Business Cycles', *The Scandinavian Journal of Economics*, 93 (2), 161-178, June

Laidler, D. E. W. (1992), 'The Cycle before New Classical Economics', in M. Belongia and M. Garfinkel (eds.). *The Business Cycle: Theories and Evidence*, London: Kluwer Academie Publishers

Lucas, R. E. Jr. (1972), 'Expectations and the Neutrality of Money', *Journal of Economic Theory*, April

Lucas, R. E. Jr. (1973), 'Some International Evidence on Output-Inflation Tradeoffs', *American Economic Review*, June

Lucas, R. E. Jr. (1987), *Models of Business Cycles*, Oxford: Basil Blackwell

Lucas, R. E. Jr. and L. A. Rapping (1969), 'Real Wages, Employment and Inflation', *Journal of Political Economy*, September/October

Mankiw, N. G. (1985), 'Small Menu Costs and Large Business Cycles: A Macroeconomic Model of Monopoly', *The Quarterly Journal of Economics*, 100 (2), 529-537, May

Mankiw, N. G. and R. Reis (2002), 'Sticky Information versus Sticky Prices: a proposal to replace the New Keynesian Phillips Curve', *Quarterly Journal of Economics*, 117, 1295-1328

Mikhail, O. (2004), 'No More Rocking Horses: Trading Business Cycle Depth for Duration Using an Economy Specific Characteristic', available at www.bus.ucf.edu/wp/Working%20Papers/2004/04-03Mikhail.pdf

Nelson, C. R. and C. I. Plosser (1982), 'Trends and Random Walks in Macroeconomic Time Series: Some Evidence and Implications', *Journal of Monetary Economics*, September

Pfaff, B. and K. Taunus (2006), 'VARS: S3 Classes and Methods for Estimating VAR and SVAR Models', available at http://www.pfaffikus/de/VARS

Ramsey, P. M., (1986), 'Increasing Returns and Long-Run Growth,' *Journal of Political Economy*, 94, 1002-1037

Rebelo, S. (2005), 'Real Business Cycle Models: Past, Present, and Future', *Economic Working Paper Series*: Northwestern University

Samuelson, P. A. (1939), 'Interactions between the Multiplier Analysis and the Principle of Acceleration', *Review of Economics and Statistics*, May

Snowdon, B., H. Vane, and P. Wynarczyk (1994), *A Modern Guide to Macroeconomics: An Introduction to Competing Schools of Thought*, Edward Elgar: Cheltenham UK

Stock, J. H. and M. W. Watson (2001), 'Vector Autoregressions', *Journal of Economic Perspectives*, 15 (4), 101-115, Fall

Summers, L. H. (1988), 'Should Keynesian Economics Dispense with the Phillips Curve?', in R. Cross (eds.), *Unemployment, Hysteresis, and the Natural Rate Hypothesis*, Basil Blackwell

Tinbergen, J. (1935), 'Annual Survey: Suggestions on Quantitative Business Cycle Theory', *Econometrica*, 3, 241-308, July

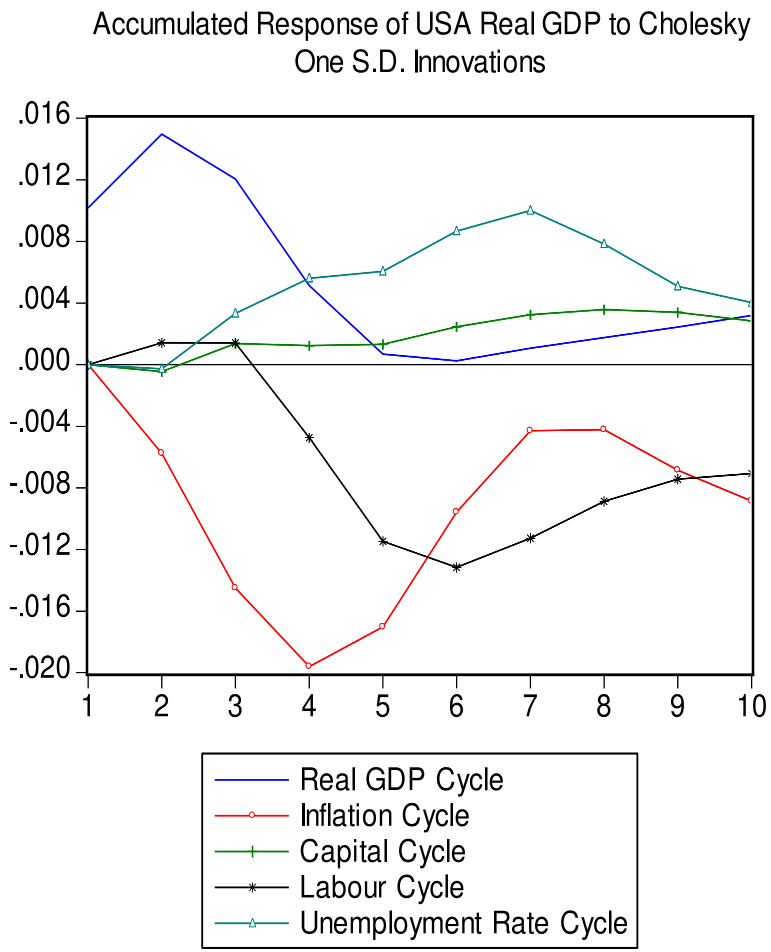
Tobin, J. (1980), 'Are New Classical Models Plausible Enough to Guide Policy?' *Journal of Money, Credit and Banking*, November

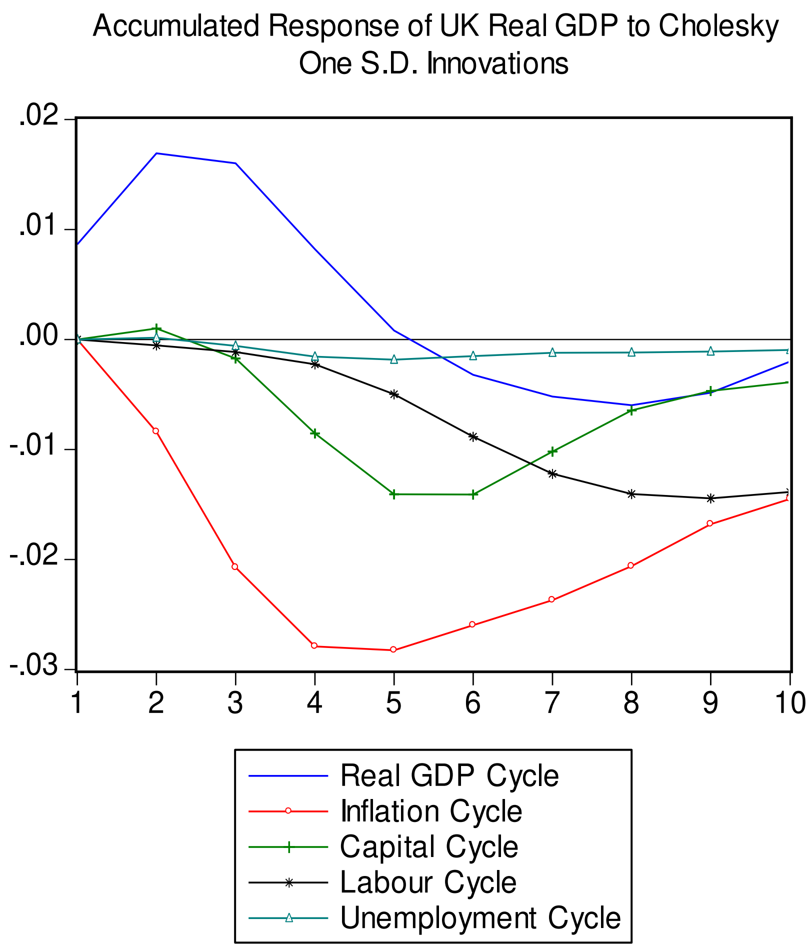
Turnovsky, S. J. (1999), 'Knife-Edge Conditions and the Macrodynamics of Small Open Economies,' available at http://www.econ.washington.edu/user/sturn/Melbourne_paper.pdf

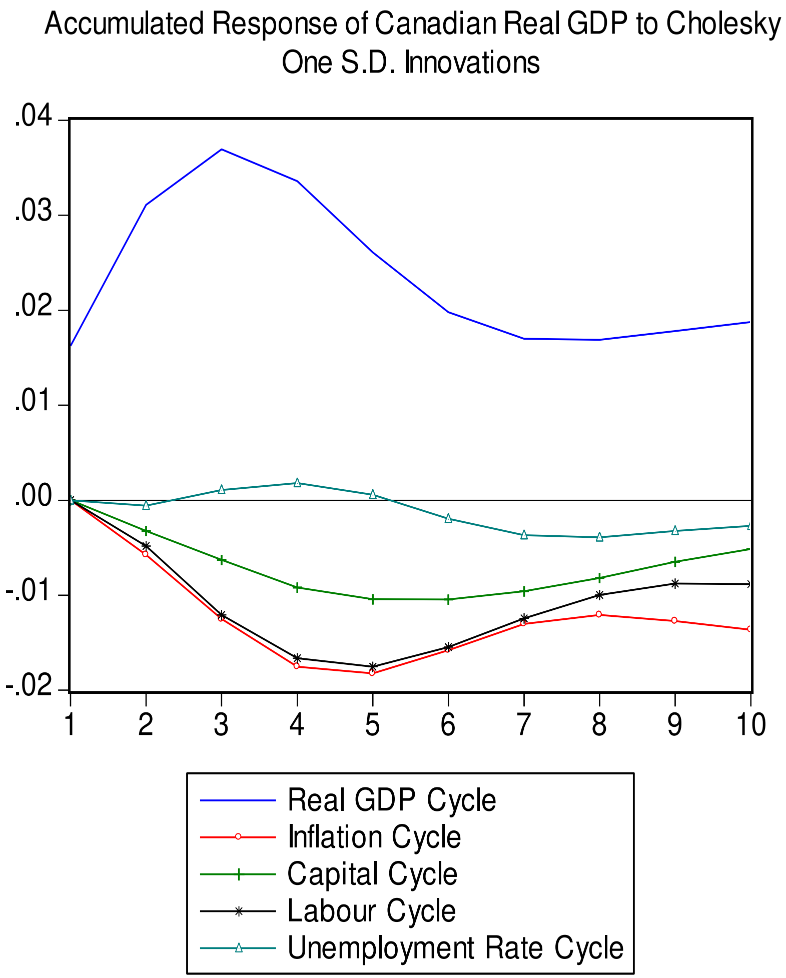
Uhlig, H. (2005), 'What are the Effects of Monetary Policy on Output? Results from an Agnostic Identification Procedure', *Journal of Monetary Economics*, 52, 381-419

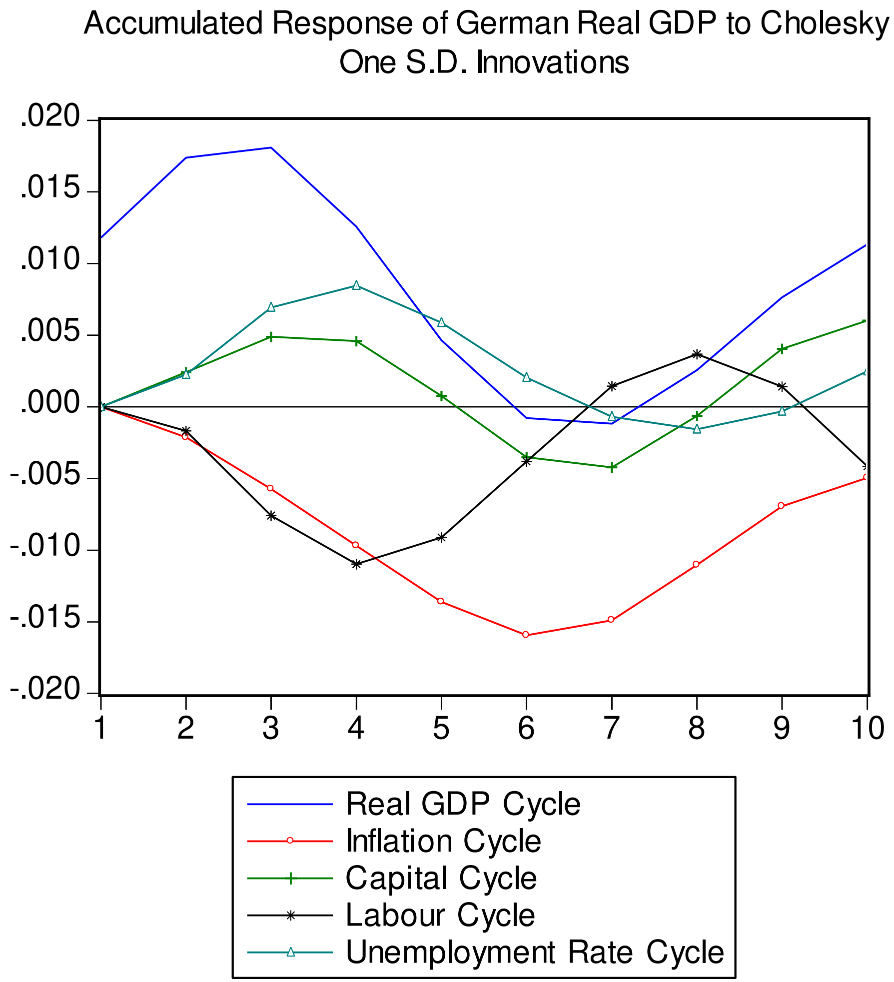
7.0 ANNEX

Annex 1: Accumulated Impulse Responses for Real GDP in USA, UK, Canada and Germany

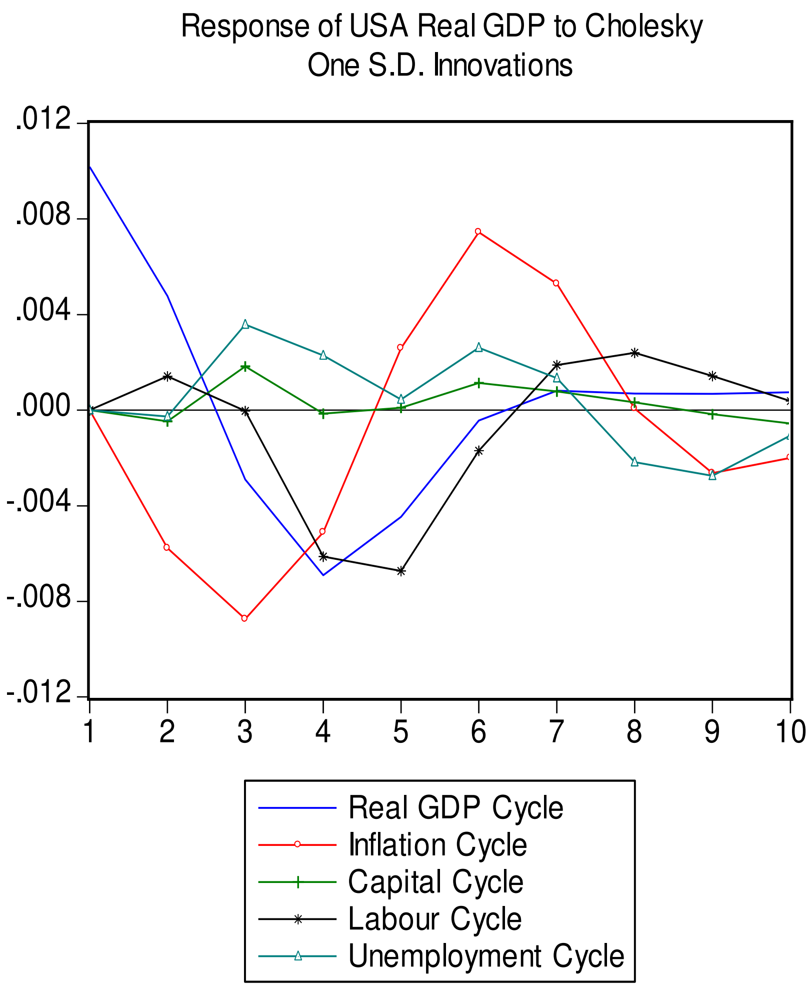


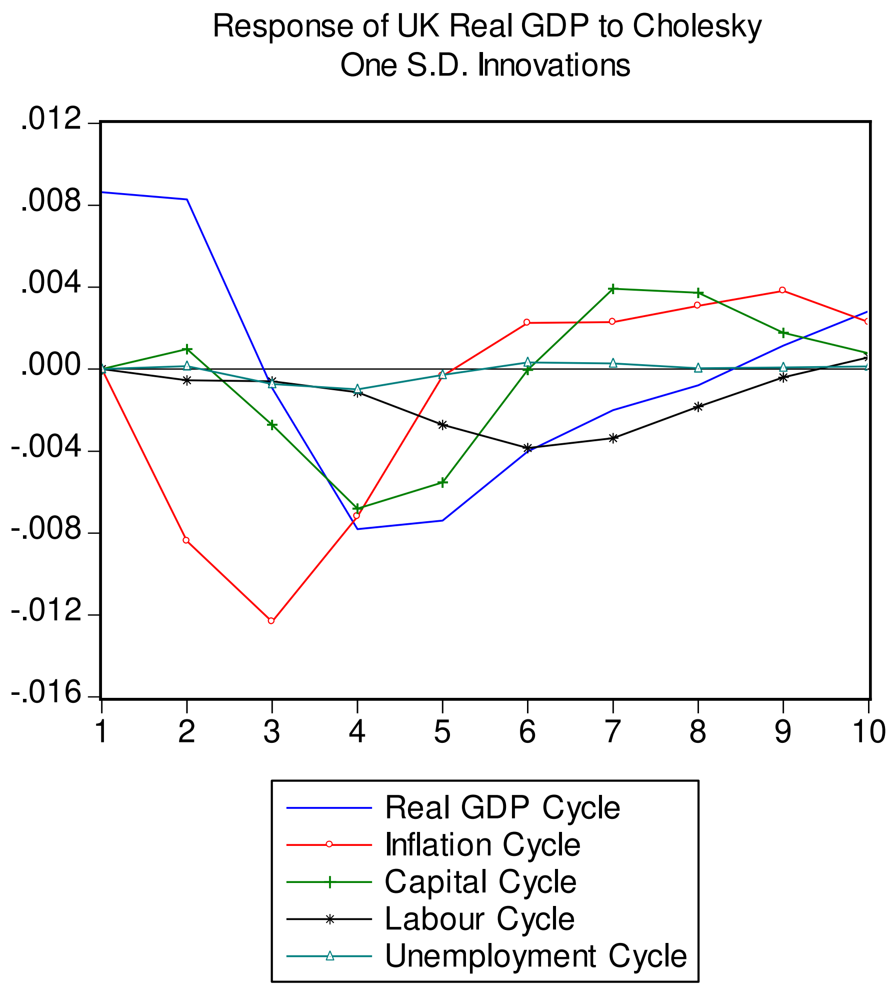


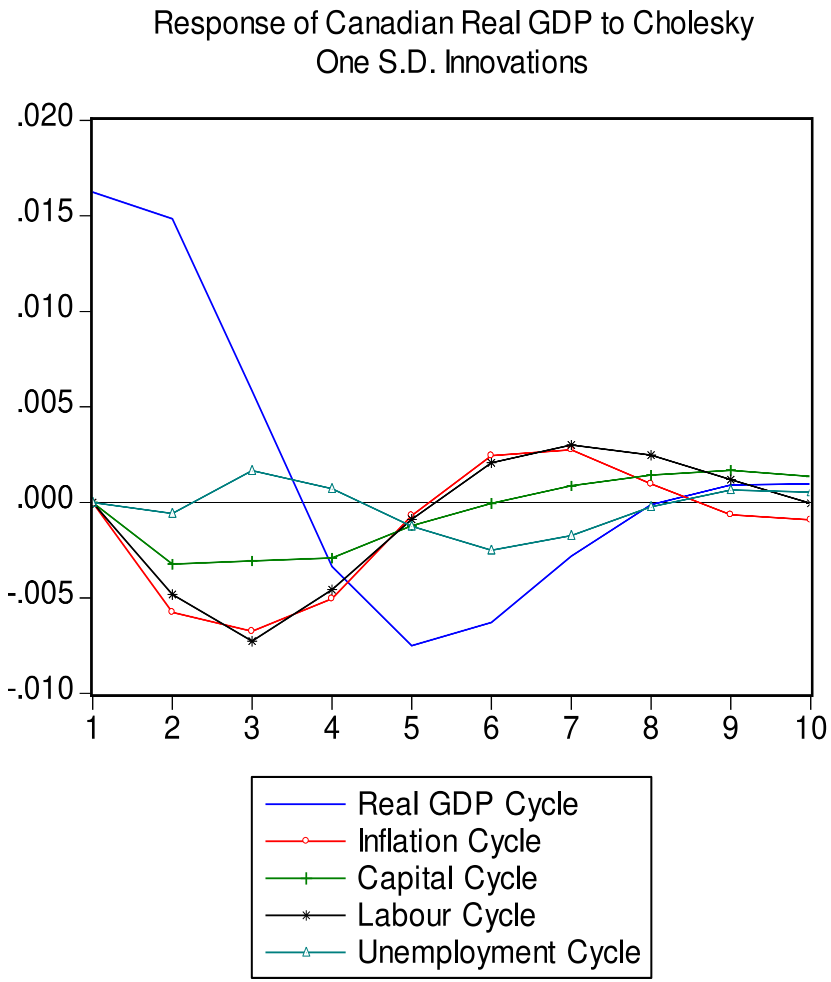

Accumulated Response of Canadian Real GDP to Cholesky One S.D. Innovations
.04
.03
.02
.01
.00
-.01
-.02
1
2
3
4
5
6
7
8
9
10
Real GDP Cycle
Inflation Cycle
Capital Cycle
Labour Cycle
Unemployment Rate Cycle

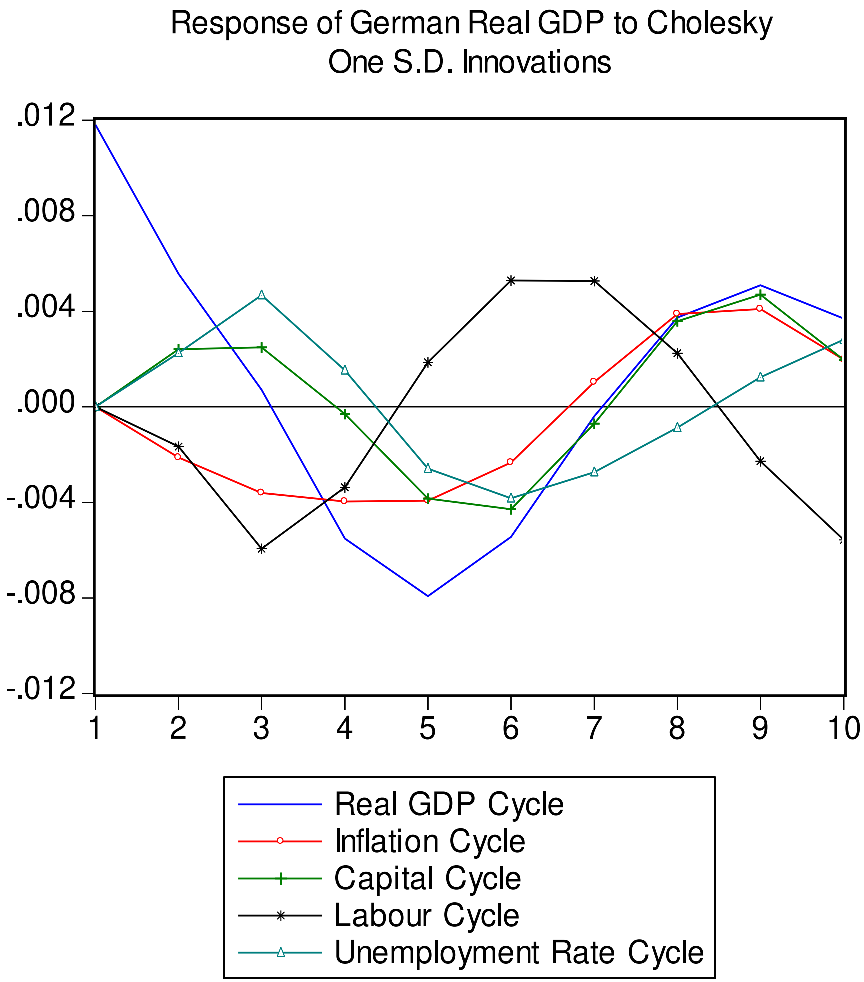

Accumulated Response of German Real GDP to Cholesky One S.D. Innovations
.020
.015
.010
.005
.000
-.005
-.010
-.015
-.020
1
2
3
4
5
6
7
8
9
10
Real GDP Cycle
Inflation Cycle
Capital Cycle
Labour Cycle
Unemployment Rate Cycle

Annex 2: Non-Accumulated Impulse Responses on Real GDP for USA, UK, Canada and Germany

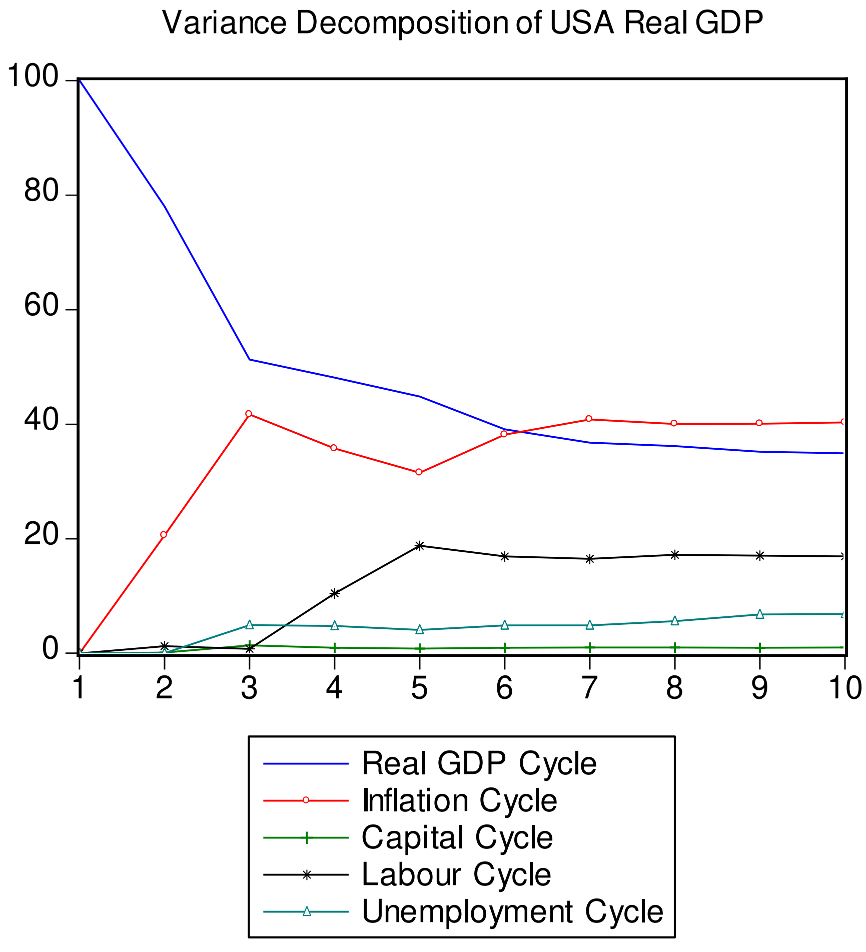


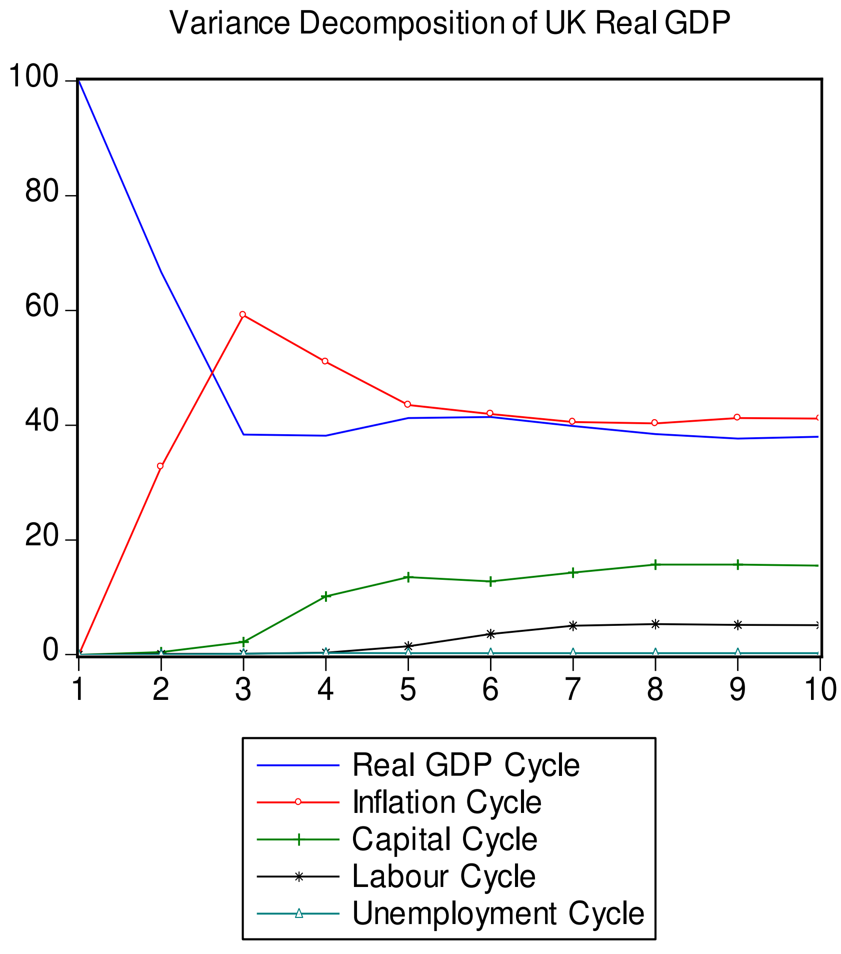


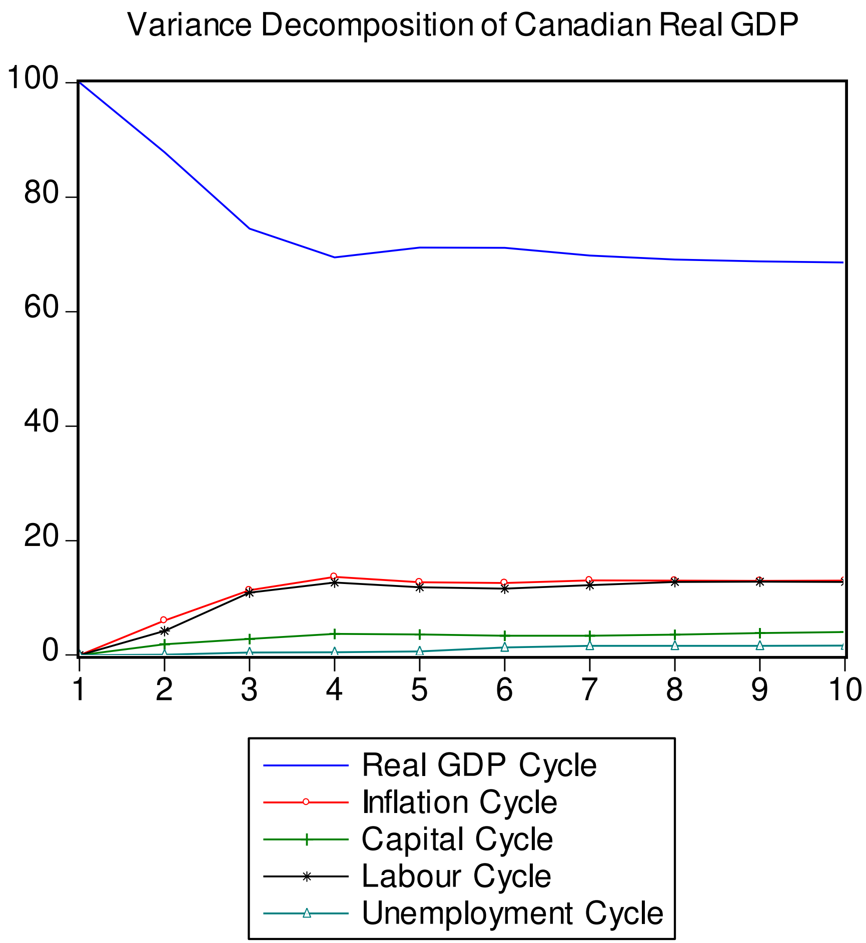

Response of Canadian Real GDP to Cholesky
One S.D. Innovations
.020
.015
.010
.005
.000
-.005
-.010
1
2
3
4
5
6
7
8
9
10
Real GDP Cycle
Inflation Cycle
Capital Cycle
Labour Cycle
Unemployment Cycle

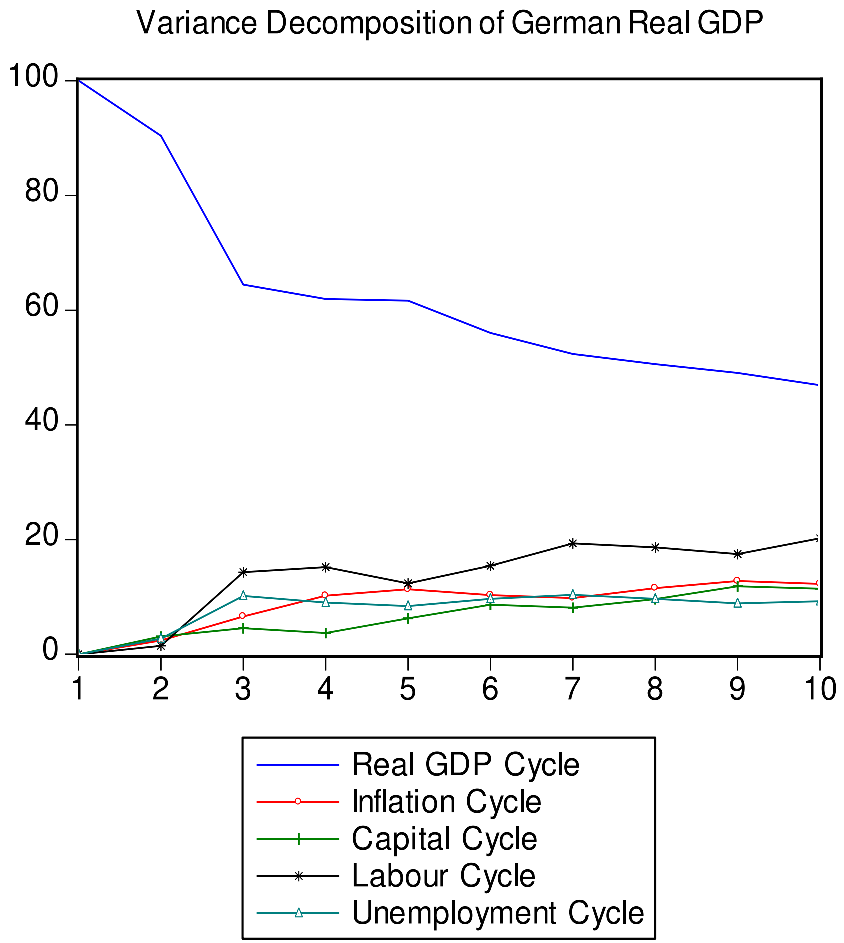

Response of German Real GDP to Cholesky
One S.D. Innovations
.012
.008
.004
.000
-.004
-.008
-.012
1
2
3
4
5
6
7
8
9
10
Real GDP Cycle
Inflation Cycle
Capital Cycle
Labour Cycle
Unemployment Rate Cycle

Annex 3: Variance Decompositions for Real GDP in USA, UK, Canada and Germany






Variance Decomposition of Canadian Real GDP
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
10
Real GDP Cycle
Inflation Cycle
Capital Cycle
Labour Cycle
Unemployment Cycle


Variance Decomposition of German Real GDP
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
10
Real GDP Cycle
Inflation Cycle
Capital Cycle
Labour Cycle
Unemployment Cycle

Annex 4: Data Used

USA Data[16]

	Real GDP	Gross Capital Formation	Inflation Rate	Total Labour Force	Working Hrs per person employed	Unemployment Rate
Unit	Billions	Billions		Millions		
1980	5,161.68	1072.29	0.48	99.303	7	0.07
1981	5,291.70	1148.99	0.53	100.4	7	0.08
1982	5,189.25	1003.65	0.56	99.529	7	0.10
1983	5,423.75	1053.83	0.58	100.822	7	0.10
1984	5,813.60	1293.29	0.60	105.003	7	0.08
1985	6,053.75	1283.82	0.62	107.154	7	0.07
1986	6,263.63	1290.87	0.64	109.601	7	0.07
1987	6,475.05	1324.15	0.66	112.439	7	0.06
1988	6,742.65	1331.34	0.69	114.974	7	0.05
1989	6,981.40	1365.42	0.72	117.327	7	0.05
1990	7,112.53	1319.66	0.76	118.796	7	0.06
1991	7,100.53	1211.71	0.79	117.713	7	0.07
1992	7,336.58	1259.32	0.81	118.488	7	0.07
1993	7,532.65	1326.50	0.84	120.259	7	0.07
1994	7,835.48	1460.69	0.86	123.071	7	0.06
1995	8,031.70	1494.70	0.88	124.908	7	0.06
1996	8,328.90	1582.49	0.91	126.72	7	0.05
1997	8,703.50	1720.86	0.93	129.572	7	0.05
1998	9,066.88	1836.22	0.95	131.476	7	0.05
1999	9,470.35	1954.11	0.97	133.501	7	0.04
2000	9,816.95	2039.96	1.00	136.901	7	0.04
2001	9,890.65	1892.87	1.03	136.939	7	0.05
2002	10,048.85	1848.99	1.04	136.481	7	0.06
2003	10,301.10	1898.49	1.07	137.729	7	0.06
2004	10,675.73	2065.86	1.10	139.24	7	0.06
2005	10,989.50	2197.46	1.13	141.714	7	0.05
2006	11,294.88	2268.69	1.17	144.42	7	0.05
2007	11,523.90	2164.30	1.20	146.05	7	0.05
2008	11,651.98	2033.50	1.25	145.368	7	0.06
2009	11,331.47	1663.57	1.24	141.655	7	0.09
2010	11,325.95	1653.14	1.24	141.756	7	0.10
UK Data						
1980	631.074	111.07	0.43	25.086	8.5	0.06
1981	622.722	99.57	0.48	24.43	8.5	0.09
1982	635.756	105.76	0.52	23.951	8.5	0.11
1983	658.798	114.87	0.55	23.775	8.5	0.11
1984	676.394	124.19	0.57	24.285	8.5	0.12
1985	700.74	127.85	0.60	24.593	8.5	0.11

[16] Note: All country-specific data are based on their national currency

	Real GDP	Gross Capital Formation	Inflation Rate	Total Labour Force	Working Hrs per person employed	Unemployment Rate
Unit	**Billions**	**Billions**		**Millions**		
1986	728.856	131.60	0.63	24.746	8.5	0.11
1987	762.107	145.02	0.65	25.239	8.5	0.11
1988	800.457	171.11	0.68	26.07	8.5	0.09
1989	818.719	181.04	0.72	26.749	8.5	0.07
1990	825.099	166.71	0.77	26.871	8.5	0.07
1991	813.61	139.86	0.82	26.163	8.5	0.09
1992	814.803	133.57	0.86	25.54	8.5	0.10
1993	832.91	132.82	0.88	25.304	8.5	0.10
1994	868.56	144.55	0.90	25.505	8.5	0.10
1995	894.988	153.63	0.92	25.819	8.5	0.09
1996	920.757	155.62	0.95	26.06	8.5	0.08
1997	951.208	163.78	0.96	26.526	8.5	0.07
1998	985.506	180.52	0.98	26.795	8.5	0.06
1999	1,019.74	184.23	0.99	27.167	8.5	0.06
2000	1,059.66	187.13	1.00	27.483	8.5	0.06
2001	1,085.75	189.11	1.01	27.71	8.5	0.05
2002	1,108.51	189.08	1.02	27.921	8.5	0.05
2003	1,139.75	190.68	1.04	28.186	8.5	0.05
2004	1,171.18	200.33	1.05	28.485	8.5	0.05
2005	1,195.28	206.41	1.07	28.774	8.5	0.05
2006	1,229.20	215.96	1.10	29.03	8.5	0.05
2007	1,266.35	230.75	1.12	29.222	8.5	0.05
2008	1,275.30	214.02	1.17	29.443	8.5	0.06
2009	1,223.19	172.74	1.18	28.949	8.5	0.07
2010	1,218.35	169.94	1.19	28.558	8.5	0.09
Canada Data						
1980	625.414	143.61	0.46	10.97	8.5	0.08
1981	647.323	160.98	0.52	11.29	8.5	0.08
1982	628.816	121.19	0.58	10.95	8.5	0.11
1983	645.906	127.79	0.61	11.03	8.5	0.12
1984	683.462	140.14	0.63	11.30	8.5	0.11
1985	716.132	149.84	0.66	11.62	8.5	0.11
1986	733.468	154.79	0.69	11.98	8.5	0.10
1987	764.664	168.95	0.72	12.32	8.5	0.09
1988	802.702	183.40	0.75	12.71	8.5	0.08
1989	823.728	191.81	0.78	12.99	8.5	0.08
1990	825.318	172.50	0.82	13.09	8.5	0.08
1991	808.051	151.82	0.87	12.85	8.5	0.10
1992	815.123	145.12	0.88	12.76	8.5	0.11
1993	834.185	148.88	0.90	12.86	8.5	0.11
1994	874.261	165.00	0.90	13.11	8.5	0.10
1995	898.814	168.58	0.92	13.36	8.5	0.10

	Real GDP	Gross Capital Formation	Inflation Rate	Total Labour Force	Working Hrs per person employed	Unemployment Rate
Unit	**Billions**	**Billions**		**Millions**		
1996	913.364	166.13	0.93	13.46	8.5	0.10
1997	951.962	197.39	0.95	13.71	8.5	0.09
1998	990.968	202.09	0.96	14.05	8.5	0.08
1999	1,045.79	212.34	0.97	14.41	8.5	0.08
2000	1,100.52	222.64	1.00	14.77	8.5	0.07
2001	1,120.15	214.87	1.03	14.95	8.5	0.07
2002	1,152.91	222.52	1.05	15.31	8.5	0.08
2003	1,174.59	234.81	1.08	15.67	8.5	0.08
2004	1,211.24	251.01	1.10	15.95	8.5	0.07
2005	1,246.06	273.81	1.12	16.17	8.5	0.07
2006	1,284.82	294.16	1.14	16.49	8.5	0.06
2007	1,319.68	306.98	1.17	16.87	8.5	0.06
2008	1,325.72	305.43	1.20	17.12	8.5	0.06
2009	1,292.05	290.31	1.20	16.75	8.5	0.08
2010	1,307.02	291.47	1.20	16.89	8.5	0.09
Germany Data						
1980	1,339.99	377.29	0.62	35.96	8.5	0.03
1981	1,341.47	341.10	0.66	35.93	8.5	0.05
1982	1,330.90	315.26	0.69	35.50	8.5	0.07
1983	1,351.59	334.36	0.71	34.99	8.5	0.08
1984	1,389.78	340.77	0.73	35.05	8.5	0.08
1985	1,420.25	333.40	0.75	35.31	8.5	0.08
1986	1,454.58	342.16	0.75	35.80	8.5	0.08
1987	1,475.96	340.06	0.75	36.06	8.5	0.08
1988	1,531.09	365.82	0.76	36.34	8.5	0.08
1989	1,591.00	394.73	0.78	36.87	8.5	0.07
1990	1,682.06	431.28	0.80	37.96	8.5	0.06
1991	1,766.36	423.84	0.83	38.62	8.5	0.05
1992	1,807.09	422.66	0.87	38.06	8.5	0.06
1993	1,792.83	397.45	0.91	37.55	8.5	0.08
1994	1,839.92	413.47	0.93	37.49	8.5	0.08
1995	1,873.76	416.39	0.95	37.55	8.5	0.08
1996	1,891.59	399.31	0.96	37.43	8.5	0.09
1997	1,923.97	406.19	0.97	37.39	8.5	0.09
1998	1,962.02	423.97	0.98	37.84	8.5	0.09
1999	1,999.92	429.72	0.99	38.34	8.5	0.08
2000	2,064.40	449.59	1.00	39.05	8.5	0.08
2001	2,088.16	406.98	1.02	39.21	8.5	0.08
2002	2,088.29	360.71	1.03	38.99	8.5	0.08
2003	2,083.46	362.44	1.04	38.64	8.5	0.09
2004	2,107.97	361.37	1.06	38.80	8.5	0.10
2005	2,123.82	358.86	1.08	38.76	8.5	0.11

	Real GDP	Gross Capital Formation	Inflation Rate	Total Labour Force	Working Hrs per person employed	Unemployment Rate
Unit	**Billions**	**Billions**		**Millions**		
2006	2,187.08	385.71	1.10	39.02	8.5	0.10
2007	2,242.00	409.52	1.13	39.69	8.5	0.08
2008	2,270.93	437.99	1.16	40.26	8.5	0.07
2009	2,143.43	367.71	1.16	40.10	8.5	0.09
2010	2,122.00	339.84	1.15	39.30	8.5	0.11