Economic Impacts of Gold Production in South Africa

by

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Abstract

The causes of rising demand pull inflation in South Africa are examined with an eye on the international price of gold given the importance of gold mining in the country. Effects of the money supply, exchange rate, foreign income, and an index of political stability are included in the model, with results showing exchange rates and the price of gold to be the major determining factors of inflation levels. Immigration of highly skilled workers from developed countries lower the marginal productivity, and emigration of highly skilled workers have the opposite effects. Depreciation of the Rand makes raw gold more affordable thereby raising supply. A higher cross price elasticity between labor and both capital and energy makes investment in new technology a feasible idea for mine owners. In addition, there is little motivation to commission new mines or re-open closed ones, which often adversely impact the environment.

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Chapter 1

Introduction

South Africa's gold industry has been the country's principal revenue earner, resulting in a robust economy with modern financial systems. Revenues from mining have provided South Africa with a vibrant infrastructure and a manufacturing sector comparable to developed countries. With the recent increase in the price of gold and the worldwide economic slowdown, investment in gold has increased, with investors seeking safe haven investments. Demand for gold has also increased in the past ten years, particularly from India and China.

Up until a few years back, South Africa was the world's largest gold producer. China surpassed South Africa as the world's largest producer in 2007. China continues to increase gold production and remained the leading gold-producing nation in 2009, followed by Australia, South Africa, and the United States. According to the US Geological Survey, South Africa produced 210 metric tons of gold in 2009.

South Africa's mineral industry operates on a free enterprise market-driven basis. Historically, mineral rights were owned by either the government or private entities. Under the new Minerals and Petroleum Resources Development Act (2004), existing mineral rights revert to the government unless companies act within 5 years to convert "old order" exploration and mining rights into "new rights" under terms specified in the new legislation, according to the South Africa Department of Minerals and Energy (2007).

South Africa is estimated, by the US Geological Survey, to have 6000 metric tons of gold reserves. A full 95% of South Africa's gold mines are underground operations, reaching depths of over 2.5 miles. Coupled with declining grades, increased depth of mining, and a slide in the gold price, costs have begun to rise, resulting in the steady fall in production. The future of the gold industry in South Africa therefore depends on increased productivity.

The main gold producing area is concentrated on the Archaean Witwatersrand Basin. The Witwatersrand basin, which has been mined for more than 100 years and has produced more than 41,000 tons of gold and remains the greatest unexploited source of gold in the world. Major new projects, new technology, new approaches to the organization of work, better labor relations and some commercial innovations are starting to reshape this industry, requiring a significant investment in research.

Besides gold, South Africa is a leading producer of other precious metals such as platinum, as well as base metals and coal. According to the South Africa Department of Minerals and Energy (2007), South Africa produced more than 59 different mineral commodities from about 920 mines and quarries, which included 116 diamond, 59 coal, 42 gold, and 21 platinum-group metals (PGM) operations. South Africa ranked first in the world production of aluminosilicates (andalusite), chromite, ferrochrome, gold, manganese, PGM, vanadium, and vermiculite, and second in production of titanium minerals (chiefly ilmenite) and zirconium. It is the world's fourth-largest producer of diamonds and experts believe there is still considerable potential for the discovery of other world-class deposits in areas that have yet to be fully exploited.

The Rand is South Africa’s official currency. According to the Bloomberg Currency Scorecard, the South African Rand was the most actively traded emerging market currency in the world as of December 2010 and it was the best-performing currency against the United States dollar (USD) between 2002 and 2005. It has consequently joined an elite club of fifteen currencies, the continuous linked settlement (CLS), where forex transactions are settled immediately, lowering the risks of transacting across time zones.

Principal international trading partners of South Africa besides other African countries include Germany, the United States, China, Japan, the United Kingdom and Spain. Other major exports besides minerals include corn, fruits, sugar, and wool. Machinery and transportation equipment make up more than one-third of the value of the country's imports. Other imports include chemicals, manufactured goods, and petroleum.

Since Minerals are a finite resource, the government of South Africa has made efforts to diversify the economy. South Africa presently has a large agricultural sector and is a net exporter of farming products. There are almost one thousand agricultural cooperatives and agribusinesses throughout the country, and agricultural exports have constituted 8% of South African total exports for the past five years. The agricultural industry contributes around 10% of formal employment, relatively low compared to other parts of Africa, as well as providing work for casual laborers and contributing around 2.6% of GDP. However; due to the aridity of the land, only 13.5% can be used for crop production, and only 3% is considered high potential land.

Manufacturing is relatively small, providing just 13.3% of jobs and 15% of GDP. Labor costs are low, but not nearly as low as in most other emerging markets, and the cost of transport, communications and general living is much higher. The South African automotive industry accounts for about 10% of South Africa's manufacturing exports, contributes 7.5% to the country's GDP and employs around 36,000 people. Other important economic activities includes off shore fishing and tourism.

Despite these positive attributes, South Africa has an extreme income inequality with the majority of residents living in informal settlements, and a high health cost burden due to a high HIV/AIDS prevalence. Other issues facing the South African economy includes high unemployment rates, crime, illegal immigration and electricity crisis.

This thesis seeks to examine the causes of rising demand pull inflation in South Africa between the years 1973 to 2007. Inflation is a rise in the general level of prices of goods and services in an economy over a period of time. When the general price level rises, each unit of currency buys fewer goods and services. This reflects erosion in the purchasing power of money, signifying a loss of real value in the unit of currency in the economy. The most common measure of price inflation is the inflation rate, which is the annualized percentage change in a general price index (usually the Consumer and Producer Price Indices) over time.

Demand-pull inflation consequently describes a situation where the rate of inflation rises, whenever aggregate demand is increased beyond the ability of the economy to produce. Hence; any factor that increases aggregate demand can cause inflation. This chapter therefore investigates the effect of interest rates, price of gold, money supply and world's GDP. However; in the long run, aggregate demand can be held above productive capacity only by increasing the quantity of money in circulation faster than the real growth rate of the economy.

In addition; this thesis will investigate the impact of migration on the physical output of gold using historical migration data, from 1983 to 2003. In the modern world, restrictions on the flow of labor are commonplace; every country imposes restrictions on immigration. Labor mobility is less prevalent in practice than capital mobility, but it remains very important. Assuming that workers are able to move between two countries, this movement will reduce the home labor force and raise the real wage at home, while increasing the labor force and reducing the real wage in the foreign country. If there are no obstacles to labor movement, this process will continue until the marginal product of labor is the same in both home and foreign country. Besides convergence of real wage rates, redistribution of the world's labor force increases the world's output as a whole.

Considering trade between South Africa and the rest of the world, in the context of the factor proportions model, South Africa can in a sense export labor and import land by exporting the labor intensive manufactures and importing land intensive grain, which might lead to a complete equalization of factor prices, without any need for migration. In the real world however, trade is indeed a substitute for international factor movement, it's not a perfect substitute. This is because each country is too different in their resources to remain unspecialized; there are barriers to trade, both natural and artificial, in addition to differences in technology and resources between countries as developed by Krugman and Obstfeld (2000) and Thompson (2006).

With gold being a labor intensive industry, labor migration is expected to exert a significant impact on the output. Labor movement between South Africa and the rest of the world involve masses of unskilled labor moving to DCs and a significant number of skilled labors moving from DCs to South Africa. The reverse is also true for migration between South Africa and the rest of the African continent.

Finally; this thesis will estimate the input factor substitution in South Africa's gold production. South African mines are relatively deeper than other sources of gold, they produce a low grade ore, and commissioning new mines often imposes prohibitive costs on investors. Recent technology has unveiled computer aided robots that could replace humans and dig deeper into the earth's crust where there are toxic gases, thereby reducing fatalities in the mines. The study covers the period from 1998 to 2008 and uses various production functions to determine the effect of factor inputs on the physical output of gold, given gold price and factor prices. The log-linear and translog production functions are estimated both as full models with all inputs and partial models with at least two inputs for comparison. Factor interactions are also tested and own and cross price effects computed. These elasticities are critical in policy formulation for energy, labor, and capital in the mining sector, given the current gold production model in South Africa.

The elasticity of substitution between productive factors is a crucial concept in the theory of production. If for instance capital and labor are the two inputs producing one kilogram of gold, a change in the market returns to labor and to capital will typically encourage cost minimizing competitive firms to alter the choice of techniques, that is; adapting factor input proportions, because a reduction in wage rates relative to capital rentals provides the motivation to switch to more labor intensive modes of production.

Outline of the Study

Chapter 2 reviews literature on previous similar studies, Chapter 3 introduces the basic models empirical framework and Chapter 4 provides the empirical results. Chapter 5 provides an explanation of the results and concluding remarks.

Chapter 2

Literature Review

Various studies have been done specifically on the relationship of major macro variables such as exchange rate and inflation and economic growth in South Africa. Khamfula (2004) suggests that the domestic nominal interest rate, corporate income tax, level of money supply, domestic savings and imports chiefly determine economic growth in South Africa. Among these factors, Khamfula (2004) explains that import shocks have a negative effect, while external shocks such as global income do not affect the long-run path of economic growth.

Inflation

Looking at inflation in South Africa, Van Der Merwe (2004) concludes that a high inflation rate negatively affects economic growth by discouraging domestic savings (and encouraging consumption and investment in non-productive goods). Households and firms turn to debt financing, while low domestic savings negatively affect the balance of payments. Van Der Merwe (2004) however puts an inflationary floor level of 8%, explaining that levels of inflation lower than this may not have any significant negative effect. This is disputed by Elbadawi et al (1997) arguing that "unpredictability of price changes" associated with inflation can be detrimental to economic growth even at low levels of inflation.

Despite these conflicting views, Van Der Merwe (2004) and Elbadawi (1997) agree that South Africa should maintain its inflation levels at par with its major trading partners, mainly countries in the South Africa Development Community (SADC). In addition, South Africa also needs to maintain a parity in inflation levels with its competitors (large producers of gold and diamond such as Botswana and Namibia), to maintain its price competitiveness.

Looking at the inflation levels in South Africa, a consistent downward trend is observed from 1990, which Aaron (2004) attributes to increased exposure to international competition, lower world inflation, increased unionization of workers (affecting expectations), high real interest, exchange rate, wage, oil price, and terms of trade shocks. In disagreement, Khamfula (2004) looks at the causal effect of foreign inflationary shocks on South Africa's inflation levels, rejecting the hypothesis that external shocks have any significance.

In estimating an inflation equation, Gordon (1981) adopts the "Lucas-Sargent approach" that estimates the inflation rate as the dependent variable rather than the wage, excluding variables representing the labor market situation.

Belonging to a monetary union can significantly lower inflation rate for a small open economy like South Africa (Bleany and Fielding (1999). On a study of the CFA countries (Communauté française d'Afrique, French Community of Africa), Bleany and Fielding (1999) find evidence of a lower inflation level and greater output, compared to similar countries with a floating exchange rate regime.

According to the South Africa 's department of Minerals and Energy (2007), South Africa ranked number one in world production of high cost metals such as gold, diamonds, and platinum-group metals (PGM), accounting for over 50% of total world output. The Minerals and Petroleum Resources Development Act (2004) stipulates that the mineral rights belong to the government and that private entities are licensed to extract. Licenses are revoked if a prospective company does not begin extraction within five years of initial issue.

South Africa has had three monetary policy regimes since 1960 according to Aaron et al (2004). The period 1960 to 1970 was based on liquid asset ratios with controls on interest rates and credit, and 1970 to 1985 had a system based on cash reserves. After 1985, the discount rate was used by the South African Reserve Bank (SARB) to influence the market interest rates. A modification to the third regime was in 1998 when SARB introduced a requirement that the repurchase interest rate be determined at an auction and earlier imposed direct controls were removed. Aaron et al (2004) however notes no significant change in the behavior of interest rates across the three regimes.

Khamfula (2004) and Aaron and Muellbauer (2000) explain that the growth in domestic money stock causes an exchange rate appreciation through rising domestic prices while domestic interest rates and import expenditures positively influence net investments.

Aaron et al (2004) examines how the exchange rate equation enters the interest rate effect. The first channel is a deflationary effect through interest rate differentials between South Africa and US, where a rise in domestic interest rates appreciates the currency. A second channel is a deflationary effect through the current account surplus. In this case, a rise in domestic interest rates by controlling demand, will increase the surplus, and hence appreciate the currency. A third channel is also a deflationary effect where expected producer inflation is reduced by a rise in interest rates, appreciating the currency. The last channel is an inflationary effect, from a weaker growth in South Africa, relative to other industrial countries.

Until 1979, the South African Rand was pegged to the British Sterling Pound with greater flexibility introduced after 1979 with a dual-currency exchange rate (Aaron et al 2004). SARB announced a commercial exchange rate on a daily basis and a financial exchange rate applied to all non-resident transactions. The dual-currency exchange rate system did a good job in establishing parity between domestic and foreign interest rates, and also to prevent capital outflows.

In 1983, the dual rates were unified, the Rand was set to be free-floating, and all controls on capital movements were removed. The new currency remained stable until 1985, when international banks recalled their loans following a political instability. The financial Rand was re-introduced following debt re-scheduling, and the dual-currency system continued until 1995, when SARB declared the currency fully free-floating, (Aaron et al 2004).

Elbadawi (1997) argues that the real exchange rate is directly and positively influenced by the stock of foreign exchange reserves, and Khamfula (2004) argues that it is negatively related to changes in the money stock but positively related to changes in domestic nominal interest rates and the foreign price.

Afekheina (2004) and Gordon (1981) explain that currency depreciation improves the current account but is inflationary, and when coupled with a restrictive financial and fiscal policy it leads to a sustainable growth rate. Gordon (1981) adds that past changes in the money supply are the dominant influence on inflation.

Khamfula (2004) finds that income is positively influenced by gross domestic savings, changes in the money stock variable and total mining production while it is negatively related to imports, total government expenditure, tax, USA interest rate, changes in US CPI, and changes in the South Africa’s nominal interest rate.

Edwards and Alves (2005) and Khamfula (2004) provide contrasting scenarios of terms of trade between South Africa and the East Asian economies, which in the absence of abundant natural resources have successfully restructured production towards dynamic high technology products. The inability of South Africa to do the same explains the relatively poor export performance. In addition, Naude and Rossouw (2008) find evidence that export diversification leads to a higher GDP and employment growth.

Gumede (2000) explains that with a high demand elasticity and trade liberalization, whenever South Africa's economy grows, imports rise exponentially hence eroding the already insufficient foreign exchange resulting in a lower GDP via a multiplier effect.

<u>Effect of Migration</u>

In regards to migration patterns, (Gerber 2005) explains that rising immigration means higher incomes for migrants and lower labor costs for firms, but also more competition in labor markets and inevitably, greater social tensions. Three factors are involved in determination of migrants from sub-Saharan Africa. First, demand-pull factors attract workers to South African mining jobs. When SA economy booms, it exerts a stronger pull on foreign labor. Jobs are more plentiful and labor supply in SA is relatively scarce. Secondly, there are supply-push factors. These are forces inside Sub-Saharan Africa that are pushing people to leave. These include recessions, but also structural changes taking place in the Sub-Saharan economy that have temporarily dislocated workers from jobs. A third factor determining migration is the existence of social networks. Existing immigrants tend to invite their economically active family and friends.

If production technologies differ between countries, it's unlikely that trade will equalize factor prices even if it equalizes commodity prices. If some goods are produced with increasing returns to scale, then trade will not equalize factor prices. If tariffs or transport costs prevent trade from equalizing commodity prices, factor prices will differ between countries. If imperfect competition or production taxes exist in some sectors, marginal costs and therefore factor prices will not be equal between countries. If there are more factors of production than traded goods, then trade in goods alone is generally not sufficient to equalize factor prices, this provides a strong argument for factor mobility, specifically labor through migration (Markusen et al, 1995).

The migrants' marginal productive contribution, which is reflected in the income they command, is generally higher in the new country than in the old, that is; the loss in production to the source country from which they depart falls short of the gain in production to the host country, resulting in a net gain to the world as a whole. As in the case of capital movement, the host country gains and the source country loses, while workers remaining behind in the source country gain.

Gerber (2005) notes that workers possess varying degree of skills and training. International migration of highly trained skilled labor from LDCs to DCs has become a cause for political concern. It's feared that this brain drain deprives developing countries the badly needed talents. The developing countries very often cannot productively absorb people who are highly trained in technical areas because the absorptive capacity of an economy only depends on its level of development and degree of industrialization. On the other hand there may be a high demand for this type of labor in the DCs, thus the difference in marginal products between the two countries is very large, with migration easily resulting in a net gain to the world. In some cases however, the country of emigration may demand compensation against the losses it incurs, especially if it has spent resources to train the migrating specialists.

There are only two cases in which the "brain drain" may cause a loss to the world as a whole: first, if diverse taxation (or wage control) systems in the two countries distort the relationship between remuneration and marginal productivity, so that educated people move to countries where their marginal productivity is lower than in their native country; second, when the activity of educated people contributes to the welfare or productivity of others in the country of residence, i.e. externality; and that externality is greater in the country of origin. Such contributions as leadership capacity, originality, creativity, and inventive ability are all examples of externalities. However; it's only when they are not rewarded through the market that externalities may reverse the gain to world welfare that comes from free migration (Mordechai 1998).

Taylor (1990) and Prothero (1974) found that South Africa engages in foreign mining labor recruitment from countries of choice. Various policies were set to encourage migrant workers from other mineral rich countries like Botswana, who are already deemed to have vast experience in the mining sector. A ban on migrant labor from Mozambique has also been imposed on various occasions as it seems to impose liabilities to employers in terms of training.

Neighboring countries like Mozambique, Malawi, Lesotho, Botswana and Swaziland claim to have contributed an aggregate of 7.1 million man years of labor since South African mines became operational. They therefore claim a legitimate share of the South African economy which can be provided for by an unrestricted provision of mining jobs to subsequent generations, (Wilson, 1976), Crush (1988) and Hartland (1953).

Majority of immigrant mining labor are in the very economically active age groups of 20 to 40 years of age. Most come from Agricultural based economy, and the net result is that Agricultural production in the source country falls and real wages rise, (Christiansen et al, 1983).

Lucas (1987) and Kilby (1961) found that migrant labor often provide capital remittances to their home countries. The rural capital formation in the home agricultural sector rises to a point where migrant labor in mining find more benefit in returning home rather than remain employed in mines. This triggers emigration. A drop in gold prices fuels the emigration to a point where wages in the mining sector in the host country equal wages in the agricultural sector in the source country.

Salt (1992) and Borgas (1994) single out technology as the limiting factor to migration of unskilled labor in favor of skilled labor. This contributes to the problem of illegal migration and also brain drain.

Gold mining sector in South Africa acts as a monopsony, rising metal prices raise real wages, and foreign labor is politically viewed as "excess labor". Tighter immigration controls are put into place to attract local labor. This distortion in labor market leads to declining gold output. (Lucas, 1985)

Berg (1961) argues that labor quantity in African mines is inversely related to rural agricultural income and changes in wage rates in the exchange sector. Once their target income is achieved, the elasticity of demand for income for migrant worker approaches zero for everything else except leisure.

Factor Substitution

Past studies on gold mining in South Africa have not dealt specifically with elasticity of factor inputs and policy implications, but there nevertheless exists numerous studies on factor substitution in other industries, and in other regions.

Thompson and Yeboah (2008) determined that fuel price reduces fuel input in corn production but inelasticity implies a rising fuel bill. Also, a fuel subsidy for corn production would increase fuel input, diminish net energy efficiency, and have a minimal impact on the overall cost of corn production.

Thompson (2008) determines that a nonrenewable resource such as gold, oil and other mining activities, when added to the neoclassical growth model introduces its own dynamics and increases the potential effect of substitution along the transitional growth path. Ley and Boccardo (2010) study the environmental cost of fossil fuel energy with an international comparison and found that large energy consumers like US, China, and Canada that account for a significant emissions, undertax fossil fuels.

Moolman (2003) found that two factors that impact negatively on the demand for labor in South Africa is the increasing labor market rigidity as measured by the power of unions, and the introduction of affirmative action legislation.

Spalding-Fetcher and Matibe (2003) found a significant social cost avoided as a result of substitution of electricity for “dirtier” fuels such as coal, wood and diesel, thereby reducing total production costs as pollution taxes decrease as firms upgrade plant and equipment.

Chapter 3

The Models

Inflation equation

The setting is an open economy model with variables for money supply, effective real exchange rate, world gold prices, US real disposable income, and inflation. The study looks specifically at demand pull inflation where aggregate demand in an economy outpaces aggregate supply. It involves inflation rising as real gross domestic product rises and unemployment falls, as the economy moves along the aggregate demand-aggregate supply curve (figure 1).

Falling unemployment rates may be associated with higher aggregate demand and perhaps an increase in the price level. Firms have an output capacity that restricts the increase in output. As a result, price increases at a higher rate than output (figure 1). As the unemployment rate falls, aggregate demand rises, shifting upwards and rightwards from AD1 to AD2. This increases output Y from Y1 to Y2. The price level increases from P1 to P2. The increase in demand and output creates an even higher demand for workers, shifting AD again from AD2 to AD3. Due to capacity constraints stated earlier, less output is produced than in the previous shift, but the price level has now risen from P2 to P3, which is much higher than the previous shift (P1 to P2).

This study however adopts the "Lucas-Sargent approach" developed by Gordon (1981), focusing directly on inflation (rather than wage) as the dependent variable. The demand pull inflation is therefore estimated as:

$$\pi = \beta_0 + \beta_1 ms + \beta_2 e + \beta_3 y^* + \beta_4 gp + \beta_5 \Omega + \varepsilon\pi$$

The variable ms is the real money supply in South Africa, Ms = nominal Ms/SA_{CPI}. This variable is expected to yield a positive coefficient consistent with Gordon (1981). The variable e is the effective real exchange rate where e = E P_{sa}/P_{us}. E is the nominal Rand rate in terms of dollars $/ra. P_{ra} is South Africa's price level, and P_{us} is the US price level. The variable e is expected to yield a negative coefficient since depreciation of the Rand viz a viz the US dollar makes SA's exports cheaper, thereby raising GDP through (X-M) given Marshall-Lerner condition. Rising domestic incomes raise aggregate demand, thereby pushing the price level higher, consistent with Afekheina (2004). The variable y* is the real world disposable income, used as a proxy for world GDP. Rising global income would raise demand for SA's goods, specifically gold. Therefore, y* is expected to yield a positive coefficient.

The variable gp* is the world gold prices. Gold is South Africa's major export, accounting for over 50% of its export revenue (South Africa Reserve Bank 2007). A rise in gold prices would have the same effect as depreciating the Rand resulting in higher inflation. X would rise as BP curve shifts out. AD curve then shifts out, so price level could rise.

The study also introduces a dummy Ω representing a political regime switch. Prior to 1994, SA had a white minority rule, and most of its African trading partners who currently import most of its output had imposed a ban on its products. After 1994, a democratically elected government was put into place and it is expected that there was a significant increase in SA's exports after 1994. The dummy takes a value of 0 for pre 1994 and 1 after 1994.

Data for E, US_{CPI}, and y* was collected from the *St. Louis Federal Reserve Bank Database (FRED II).* Data for SA_{CPI}, SA_{PPI} and ms was collected from the *South Africa Reserve*

*Bank(SARB).*Data for world gold prices was collected from the *World Gold Council.* All data has been converted into log form.

Effect of migration

In a similar small open economy setting, this model uses gold quantity, as the dependent variable with world gold price, global immigration, global emigration, and real effective exchange rate between the United States and South Africa as the explanatory variables. The study looks specifically at the short term effect resulting from the movement of persons, in and out of South Africa, on the physical volume of gold output. The study goes further to investigate how specific regions in the world would impact the supply of gold. The theoretical model is:

Gold supply= f (gold price, global immigration, global emigration, real effective exchange rate)

- Gold supply is the physical volume of mining production.
- Gold price is the world price of gold i.e. price per ounce of gold dust.
- Global immigration is the number of economically active persons entering South Africa from a foreign country, with an intention to seek both employment and citizenship.
- Global emigration is the number of economically active South African citizens, moving out of South Africa to a foreign country, with the intention of seeking employment and citizenship in the foreign country.
- Real effective exchange rate is the product of nominal exchange rate between South Africa and U.S. and the PPI ratios ($e= EP_{sa}/P_{us}$)

This model is replicated over the five regions in the world i.e. Africa, Asia, Europe, Americas and Oceania to determine the regional impact of migration in gold output in South Africa. The period of study is 1983 to 2003; all data is monthly and in log form, thereby providing coefficients that are elasticities. All data is available online from the South African government portal, and from the Federal Reserve Bank of St. Louis (FRED II database).

The following six models will be estimated to study the specific effect of regional migration on gold supply.

$$Qs = \beta_0 + \beta_1 P + \beta_2 Iglobal - \beta_3 Eglobal - \beta_4 e + \varepsilon Qs$$

$$Qs = \alpha_0 + \alpha_1 P + \alpha_2 Iafrica - \alpha_3 Eafrica - \alpha_4 e + \varepsilon Qs$$

$$Qs = \Omega_0 + \Omega_1 P + \Omega_2 Iasia - \Omega_3 Easia - \Omega_4 e + \varepsilon Qs$$

$$Qs = \zeta_0 + \zeta_1 P + \zeta_2 Ieurope - \zeta_3 Eeurope - \zeta_4 e + \varepsilon Qs$$

$$Qs = \delta_0 + \delta_1 P + \delta_2 Iamericas - \delta_3 Eamericas - \delta_4 e + \varepsilon Qs$$

$$Qs = \theta_0 + \theta_1 P + \theta_2 Ioceania - \theta_3 Eoceania - \theta_4 e + \varepsilon Qs$$

where;

- Qs≡ Physical quantity of gold produced
- P≡ World price of gold i.e. price per ounce of gold dust (+)
- Iglobal≡ Number of economically active persons leaving SA (+)
- Eglobal≡ Number of economically persons entering SA (-)
- e≡ Real exchange rate(-)
- Iafrica≡Number of economically active persons leaving SA for the rest of Africa(+)
- Eafrica≡Number of economically persons entering SA from the rest of African continent. (-)
- Iasia≡Number of economically active persons leaving SA for Asia(+)

- Easia≡Number of economically persons entering SA from Asia(-)
- Iamericas≡Number of economically active persons leaving SA for Americas(+)
- Eamericas≡Number of economically persons entering SA from Americas(-)
- Ioceania≡Number of economically active persons leaving SA for Oceania(+)
- Eoceania≡Number of economically persons entering SA from Oceania(-)

The signs (+/-) besides each variable show the expected signs of the coefficients. The world price of gold is expected to yield positive coefficients in a supply function, and so is immigration. Gold mining in South Africa is a labor intensive industry, employing millions of semi-skilled and unskilled labor. Immigration lowers local real wages enabling the profit seeking mining companies to increase supply.

Emigration however; would be expected to yield the opposite effect as immigration, due to rising local real wages. Rising real effective exchange rate implies depreciation of the Rand against the US. Dollar. This is good for gold supply since gold becomes less expensive in the foreign country, thereby raising demand.

Translog Cost Factor Shares and Substitution

The three-input translog production function can be written in terms of logarithms as follows,

$$LnQ = \beta_0 + \beta_1 LnK + \beta_2 LnL + \beta_3 LnE + ½ (\beta_4 LnK^2 + \beta_5 LnKLnL + \beta_6 LnKLnE + \beta_7 LnL^2 + \beta_8 LnLLnE + \beta_9 LnE^2)$$

where Q is the physical quantity of raw gold output, K is real stock of capital input, measured by an index of physical plant and machinery used in the industry. L is labor input, representing the total number of workers engaged in mining and E is energy input, which is the physical volume of electricity consumed by the entire mining industry in South Africa in kilowatts/hr. β_0 is the intercept or the constant term. $\beta_{0,}$ $\beta_1$and β_3 are first derivatives. β_4, $\beta_7$and β_8 are own second derivatives. β_5, β_6 and β_8 are cross second derivatives. Cross and own price substitutions use *w*, *r*, and *e* which represent corresponding wage levels, the real interest rates, and the cost of electricity in kilowatts/hr. All data is time series, monthly covering the periods from 1998 to 2008.

Under perfect competition assumption, output elasticity with respect to input equals to cost share of that input. Thus, we can get a system of equations from differentiating the translog production function with respect to each factor input,

$$LnQ/LnK = \theta_K + \theta_{KK\,LnK} + \theta_{KL\,LnL} + \theta_{KE\,LnE}$$

$$LnQ/LnL = \theta_L + \theta_{LK\,LnK} + \theta_{LL\,LnL} + \theta_{LE\,LnE}$$

$$LnQ/\ LnE = \theta_E + \theta_{EK\,LnK} + \theta_{EL\,LnL} + \theta_{EE\,LnE}$$

where θ_K represents the average cost share of capital, θ_{KK} , θ_{KL}, and θ_{KE} represent constant capital share elasticity with respect to capital, capital share elasticity with respect to labor, and capital share elasticity with respect to energy input respectively. θ_{EK}, θ_{EL} and θ_{EE} are constant energy share elasticity with respect to capital, with respect to labor and with respect to energy. The ordinary regression analysis is used, followed by the usual hypothesis testing procedures.

The study also checks for symmetry, constant returns to scale, and existence of separability. So symmetry restriction on parameters is imposed,

$$\theta_{KL} = \theta_{LK}\ ,$$

$$\theta_{KE} = \theta_{EK}$$

$$\theta_{EL} = \theta_{LE}\ .$$

For constant returns to scale, the following restrictions are imposed:

$\theta_K + \theta_L + \theta_E = 1$,

$\theta_{KK} + \theta_{LK} + \theta_{EK} = 0$,

$\theta_{KL} + \theta_{LL} + \theta_{EL} = 0$,

$\theta_{KE} + \theta_{LE} + \theta_{EE} = 0$.

For weak separability, the study checks whether the linear separability restrictions are satisfied. The linear restriction might be: $\theta_{LE} = \theta_{EK} = 0$ etc. Then, concavity of the function should be checked. Concavity of the function is satisfied if the Hessian determinant of parameter estimates is negative semi definite. Finally, the study measures the curvature of isoquant by estimating partial elasticities of substitution.

Production is log-linear if the logarithm of gold output is a linear function of the logarithms of inputs. This simpler function is also estimated for comparison following the above steps. Both the partial (KL) and full models (KLE) are evaluated. The functional form is;

$LnQ = \beta_0 + \beta_1 LnK + \beta_2 LnL + \beta_3 LnE$ for the full model and

$LnQ = \beta_0 + \beta_1 LnK + \beta_2 LnL + \beta_3 LnE$ for the partial model.

Chapter 4

Empirical Results

Inflation Effects

Variables in a time series regression should be stationary, converging to a dynamic equilibrium, or standard errors would be understated (Enders 1995). Autoregressive AR (1) stationarity tests for the inflation equation are reported in Table 1. Inflation π is stationary with white noise residuals. All residuals are checked for white noise with zero means, low autocorrelation by Durbin Watson statistics (DW > 1.26 for lack of positive autocorrelation and DW < 2.74 for lack of negative autocorrelation), and homoskedasticity by ARCH(1) tests. The rest of the variables are nonstationary.

All variables are difference stationary by Dickey-Fuller DF tests (Table 1) as suggested by the difference plots in Figure 2. The real exchange rate e is difference stationary with the Dickey Fuller test with a constant, DFc. Inflation and world gold prices gp* are stationary with the Dickey Fuller test without a constant, DF. US disposable income Y* is difference stationary with Augmented Dickey Fuller test, ADF, and money supply ms is stationary with the Dickey Fuller test with a constant, DFc.

Regression in levels produces spurious results and variables are cointegrated by an Engle-Granger EG test. This regression is reported in Table 2,

$$\pi = \beta_0 + \beta_1 ms + \beta_2 e + \beta_3 y^* + \beta_4 gp + \beta_5 \Omega + \varepsilon\pi$$

The variable ms and e produces coefficients with unexpected signs, y* is insignificant, but gp* produces a significant coefficient suggesting that evidence of demand pull inflation in South Africa is determined by rising world gold prices.

The residual ε_π from the spurious model is stationary by the Engle-Granger EG test, satisfying the critical t-statistic -3.18. Analysis proceeds with an error correction model (ECM). The residual ε_π from the spurious model is included in the ECM

$$\Delta\pi = b_0 + b_1\Delta ms + b_2\Delta e + b_3\Delta y^* + b_4\Delta gp^* + b_\gamma\varepsilon_\pi + \varepsilon_{ECM}.$$

As reported in Table 3, only the spurious residual coefficient b_γ and gold price are significant. There is no autocorrelation by the DW test and no heteroskedasticity by the ARCH (1) test. The insignificant difference coefficients imply no transitory effects but the significant error correction term implies adjustment relative to the dynamic equilibrium. The associated difference model without the spurious residual produces no significant results except for gp*.

Effects of exogenous variables on inflation are reported in Table 4, derived by multiplying the error correction coefficient b_γ in Table 3 by each of the spurious coefficients in Table 2. The reported t-statistics are derived through error propagation calculation.

The insignificant 0.81 money supply coefficient implies that the level of money supply by the SARB has no effect on inflation. The -0.64 effective real exchange rate e elasticity is evidence that appreciation/depreciation of the Rand has a negative/positive effect on the domestic price level. Higher global gold prices have a positive effect on the rate of inflation with an elasticity of 0.49 reflecting the importance of gold as South Africa's major export.

US disposable income does not yield a significant coefficient suggesting that rising incomes in the US may not be a reflection of the level of incomes globally or rather; US may not be the single largest importer of gold from South Africa. A test for the evidence of a structural break shows that the political regime switch is not important in this analysis and results are not reported.

The explanatory power of the ECM is modest with an adjusted R^2 of 0.41. The model predicts inflation as pictured in Figure 3. There is no pattern in the white noise difference between predicted and actual inflation relative to actual inflation while Figure 4 plots the predicted change in inflation versus the actual change.

Migration Effects

In the migration equation, all variables are difference stationary with white noise residuals (Tables 5 and 6) and also as shown by residual plots in figures 17, 19, 21, 23, 25, 27, 29, and 31. All residuals are checked for white noise with zero means, low autocorrelation by Durbin Watson statistics (DW>1.26 for lack of positive autocorrelation and DW>2.74 for lack of negative autocorrelation), and homoskedasticity by ARCH (1) tests.

Gold quantity, emigration, and real effective exchange rate are difference stationary by Peron test. World gold price is difference stationary with Dickey Fuller test with a constant, while immigration is difference stationary by the Dickey Fuller test without a constant. Migration variables at the regional level are all difference stationary by Peron test as shown in Table 5. Figures 6 through 15 show migration patterns between South Africa and specific countries within various regions, while figures 16, 18, 20, 22, 24, 26, 28, and 30 shows the variables in levels.

Regression in levels produces spurious results and variables are cointegrated by an Engle-Granger EG test. This regression is reported in Tables 7, 10, 13, 16, 19, and 22.

$$Qs = \beta_0 + \beta_1 P + \beta_2 Iglobal - \beta_3 Eglobal - \beta_4 e + \varepsilon Qs$$

$$Qs = \alpha_0 + \alpha_1 P + \alpha_2 Iafrica - \alpha_3 Eafrica - \alpha_4 e + \varepsilon Qs$$

$$Qs = \Omega_0 + \Omega_1 P + \Omega_2 Iasia - \Omega_3 Easia - \Omega_4 e + \varepsilon Qs$$

$$Qs = \zeta_0 + \zeta_1 P + \zeta_2 Ieurope - \zeta_3 Eeurope - \zeta_4 e + \varepsilon Qs$$

$$Qs = \delta_0 + \delta_1 P + \delta_2 Iamericas - \delta_3 Eamericas - \delta_4 e + \varepsilon Qs$$

$$Qs = \theta_0 + \theta_1 P + \theta_2 Ioceania - \theta_3 Eoceania - \theta_4 e + \varepsilon Qs$$

Gold price in the global results (table 7) produces an insignificant coefficient with the correct sign. Global immigration, emigration and Rand depreciation appear to hurt gold supply. They all produce negative coefficients which are highly significant. The residual *εQs* from the spurious model is stationary by the Engle-Granger EG test, satisfying the critical t-statistic of -3.18.

Africa's spurious model shows a similar effect of migration on gold supply (table 10) as the global result. Asia's spurious results (table 13) show a similar result except that immigration has a positive effect on gold output. Europe (table 16) provides a similar result but with an insignificant immigration coefficient while Oceania (table 19) yields a positive emigration coefficient and a negative coefficient for the gold price. America's spurious model (table 22) yields a positive insignificant coefficient for immigration. All the regional residuals from the spurious models are stationary by the Engle-Granger EG test, also satisfying the critical t-statistic of -3.18.Analysis proceeds with an error correction model (ECM). The residual *εQs* from the spurious model is included in the ECM.

$$\Delta Qs = \beta_0 + \beta_1\Delta P + \beta_2\Delta Iglobal - \beta_3\Delta Eglobal - \beta_4\Delta e + \beta\gamma Qs + \varepsilon ECM$$

$$\Delta Qs = \alpha_0 + \alpha_1\Delta P + \alpha_2\Delta Iafrica - \alpha_3\Delta Eafrica - \alpha_4\Delta e + \alpha\gamma Qs + \varepsilon ECM$$

$$\Delta Qs = \Omega_0 + \Omega_1\Delta P + \Omega_2\Delta Iasia - \Omega_3\Delta Easia - \Omega_4\Delta e + \Omega\gamma Qs + \varepsilon ECM$$

$$\Delta Qs = \zeta_0 + \zeta_1\Delta P + \zeta_2\Delta Ieurope - \zeta_3\Delta Eeurope - \zeta_4\Delta e + \zeta\gamma Qs + \varepsilon ECM$$

$$\Delta Qs = \delta_0 + \delta_1\Delta P + \delta_2\Delta Iamericas - \delta_3\Delta Eamericas - \delta_4\Delta e + \delta\gamma Qs + \varepsilon ECM$$

$$\Delta Qs = \theta_0 + \theta_1\Delta P + \theta_2\Delta Ioceania - \theta_3\Delta Eoceania - \theta_4\Delta e + \theta\gamma Qs + \varepsilon ECM$$

Results are reported in Tables 8, 11, 14, 17, 20, and 23. In the global model (table 8), gold price, real effective exchange rate, and the spurious residual are positive and significant. Africa's ECM (table 11) yields a significant emigration coefficient with a negative sign, in addition to a significant spurious residual while Asia only yield a significant spurious residual (table 14). Europe (table 17) yields a significant emigration coefficient with a negative sign, and a significant spurious residual. Both Oceania (table 20) and Americas (table 23) yield significant immigration coefficients with a positive and a negative signs respectively in addition to significant spurious residuals. The insignificant difference coefficients imply no transitory effects but the significant error correction term implies adjustment relative to the dynamic equilibrium.

Effects of exogenous variables on gold supply are reported in tables 9, 12, 15, 18, 21, and 24. Coefficients are derived by multiplying the error correction coefficients $\Psi\gamma$in tables 7, 10, 2.8, 13, 19, and 22, by each of the spurious coefficients in tables 8, 11, 14, 17, 20, and 23. The reported t-statistics are derived through error propagation calculation: $\sigma_{\gamma} = \gamma((\sigma_{\alpha}/\alpha)^{2} + (\sigma_{\beta}/\beta)^{2})^{.5}$.

In the global effects (table 9), the insignificant 0.019 elasticity implies that the world price of gold has little or no effect on gold supply, inconsistent with Lucas (1985) and so is the insignificant 0.008 elasticity on immigration. A significant -0.0232 elasticity for emigration means that emigration has a strong negative effect on gold supply, while depreciation of the Rand impacts supply very positively with an elasticity of 0.051, consistent with Krugman et al (2000).

South Africa's migration in relation to the rest of African continent (table 12) shows that immigration is good for gold supply with a significant 0.0048 elasticity while emigration has an opposing effect with a -0.0103 elasticity. This is consistent with Wilson (1976) and Crush (1988) Price and exchange rate are insignificant here with elasticities of -0.0007 and 0.0519 respectively.

Migration in both Asia (table 15) and Americas (table 24) respectively do not have any effect on gold output in South Africa. All coefficients are insignificant with price yielding a coefficient with a wrong sign. Europe's effect (table 18) has an emigration impacting gold supply positively with an elasticity of 0.0079. The rest of the coefficients are insignificant with price yielding a wrong sign. Immigration effects from Oceania (table 21) hurt gold supply with an elasticity of -0.00906. The rest of the exogenous variables do not have any significant effects

Production Functions

Stationarity results for the production function are reported in Table 25. Gold output *Q*, capital *K*, and labor *L* are difference stationary without a constant, whereas real interest rates r and the wage rate w are difference stationary with a constant. Electricity input *E* and its corresponding cost *e* are both difference stationary by Peron.

Figure 32 shows gold output *Q*'s growth remain constant with a slight decline from 2004 onwards. Capital *K* shows a steady increase over the period of study, while labor *L* keeps fluctuating by small margins. Electricity production is constant throughout the period, possibly because an inefficient government agency (Eskom) monopolizes electricity production and supply. The series are not stationary but plots of differences in Figure 33 suggest they are difference stationary. The suggestion is therefore to estimate the production function as a difference equation or an error correction model if the series are cointegrated.

Table 26 reports preliminary estimates of the KL and KLE models in log linear form. Regressions on levels of variables in the first two columns have high residual correlation as expected based on the trends in Figure 33 and pretests, and there are high degrees of heteroskedasticity in the residuals. The KLE model decreases in fitness compared to the KL model based on the Akaike Information Criterion AIC. Variables in the two models are not cointegrated by Engle-Granger EG tests.

The difference regressions in the second two columns of Table 26 yield a strong energy and labor effect. Capital has a negative impact in the ΔKLE model. Coefficients in the ΔKLE regression more nearly reflect constant returns with a sum of 0.81 (0.26) and the null hypothesis that their sum equals one is not rejected at the 10% level. The downside of these two last models is the extremely poor goodness of fit with R^2 of .003 and .008 respectively. Figure 34 plots residuals of the KLE, KL, ΔKLE, and ΔKL regressions. The unexplained growth reflected by the constant of the difference regression leaves room for technological progress or for other specifications.

Table 27 reports unsuccessful KLE translog estimates. The translog model in level form in the first column has a high degree of heteroskedasticity. The series are cointegrated according to the Engle-Granger EG statistic suggesting the error correction model ECM in the last column. The translog difference regression reveals no significant interactive terms and they erode significance in the last column of Table 26. The error correction coefficient is significant in the ECM.

<u>Cross Price Elasticities</u>

The three inputs are substitutes given insignificance of the interaction terms. Cross price elasticities are derived from the marginal products and related second order terms in the symmetric Hessian matrix, table 28.

Invert the Hessian matrix to find the partial derivatives of inputs with respect to input prices. For instance, $\partial E/\partial w$ is the cofactor of that element in the inverse matrix. The key elements of the inverse matrix are:

$$\begin{pmatrix} \partial K/\partial r & \partial L/\partial r & \partial E/\partial r \\ \partial K/\partial w & \partial L/\partial w & \partial E/\partial w \\ \partial K/\partial e & \partial L/\partial e & \partial E/\partial e \end{pmatrix} \quad \text{shown in table 29}$$

Evaluate the cross and own price elasticities at the derived marginal products and means according to $\varepsilon_{Ew} = (\partial E/\partial w)\ w/E = (\partial E/\partial w)\ Y_L/E_\mu$. Means of the inputs are $K_\mu = 94$, $L_\mu = 2208$, and $E_\mu = 17744$

Table 30 presents the matrix of cross and own price elasticities. Labor has the strongest own elasticity in the KLE function. An increase of 10% in the wage level lowers labor input by 9.9% (1.2% in translog) but the labor bill rises. Capital input increases 0.06% (2.8% in translog) and energy input 0.06% (1.2% in translog). An increase of 10% in the real interest rate lowers capital input by 0.3% (0.01% in LKE). There is substitution toward capital with increased input of 1.3% (2.0% in KLE) and similar substitution toward energy. An increase of 10% in the price of energy input lowers energy input 0.1% (2.1% in KLE), strongly increasing labor input by 9.9% (7.9% in KLE) and a similar magnitude in energy.

Chapter 5

Summary and Conclusions

The analysis concludes that the exchange rate and gold prices are important in determining the rate of inflation in South Africa. Money supply is found to be unimportant, inconsistent to Gordon (1981). This could have been as a result of the Growth, Employment and Redistribution (GEAR), a policy developed by South Africa's government that included Inflation targeting. That is a monetary policy in which a central bank attempts to keep inflation in a declared target range, typically by adjusting interest rates.

According to the South Africa Reserve Bank (2000), adjusting interest rates will raise or lower inflation through the adjustment in money supply, because interest rates and money supply have an inverse relationship. SARB also publicly declares the forecasted interest rates such that; if inflation appears to be above the target, SARB would raise interest rates and vice versa. Further research in this analysis therefore would be to include a variable representing inflation targeting and measure how that individually affects the level of inflation.

Globally, immigration of economically active persons into South Africa increases labor and reduces the real effective wage rate, consistent with Gerber (2005). It is assumed that mining companies are operating at less than full capacity and that they are profit maximizing entities. They are able to adjust output in the short run. Therefore; with the industry being labor-intensive, an influx of workers would lower the marginal product of labor but increase the total product in the short run. This is clearer with immigration from the rest of the African continent, which provides the bulk of unskilled labor consistent with Mordechai (1998). Immigration of highly skilled labor from developed countries lowers the marginal productivity of the plant to a point whereby the total product falls significantly. This effect is more pronounced in immigration viz a viz Oceania.

Emigration under the same assumption has the opposite effect as immigration, globally and also in Africa, while depreciation of the Rand makes raw gold and gold products more affordable in the world market, thereby raising supply, consistent with Thompson (2006).

Except for Africa and Oceania, migration patterns regionally do not have a very strong effect on gold supply. One of the reasons could be that the study did not distinguish between skilled, semi-skilled and unskilled labor. These effects would undoubtedly provide deeper insights into migration effects. It's possible that the current model has effects of skilled labor canceling out the effects of unskilled labor, thereby yielding insignificant coefficients.

There are three major issues in South Africa's mining. First; its adjustment of physical output in response to rising world metal prices, while facing rising production costs caused by declining quality of mines. Secondly, the environmental impact of deep shaft mining and thirdly; miner's safety as described by the international occupation safety and health standards.

This study addresses all these issues. A rising labor cost reduces labor input in gold mining, but inelasticity implies a rising wage bill. Substitution towards machinery and energy is moderate at 1.2% (translog) each for a 10% increase in the wage rate. Mine owners have a choice of employing physical labor to dig deep underground, or employ technologically advanced computer aided robots. The latter option enables mining at depths that human labor cannot safely work. This increases physical output while saving on wage bill, and avoiding fatalities resulting from mine accidents, consistent with Matibe et al (2003).

Another benefit for substituting machinery for humans is that it discourages re-opening of obsolete mines, or establishing new ones, consistent with Rockerbie (1999) and Ellison (1986). This reduces environmental degradation and eliminates costs associated with commissioning new mines. These benefits would however only be realized if the cost for this later technology is covered by revenues accrued from the increased output of physical gold.

The strong substitution of capital and labor for energy shows increased sensitivity of mine owners to energy prices. Electricity is provided by a government monopoly unlike other sources of energy. The government may seek to control oil prices to protect the industry from the volatility caused by fluctuating oil prices. Investing in complementary sources of energy like wind and nuclear is also a feasible idea, in a bid to lower energy prices and stabilize the prices of raw gold.

Table 1: Stationarity Analysis for Inflation Equation

	AR(1) Coef+2(se)<1	DF -1.95<t<0 DW(1.217,1.322	DFc -3.00<t<0 F<5.18	DFt -3.60<t<0 F<5.68	ADF -3.60<t<0 F<7.24
Π	0.6+2(0.13)=0.88 DW=1.82 ARCH(1) = 0.18	t=-0.77 DW=2.12 ARCH(1)=0.35			
m_s	1.02+2(0.03)=1.1	t=2.56	t=0.59	t=-2.27 DW=2.01 ARCH(1)=1.3 F=0.43	
E	0.77+2(0.11)=0.98 DW=1.58 ARCH(1)=1.54 F=0.78	t=-0.2 F=0.03 DW=1.69 ARCH(1)=0.18			
Y*	0.97+2(0.06)=1.09	t =0.29	t =0.72	t =0.87	t =-1.91 F=0.68 DW=1.45 ARCH(1)=0.63
Gp*	0.83+2(0.09) =1.03	t=-0.2 F=0.03 DW=1.69 ARCH(1)=0.18			

Table 2: Levels Model

	Coefficient	t-statistic
Constant	5.68***	3.5
Ms	-1.27***	-3.57
E	0.99***	2.44
Y*	0.39	0.82
Gp*	0.76***	2.92
EG t =-3.99** DW=1.83 ARCH(1)=0.97	**5% ***1%	AdjR^2 =0.45 DW=1.15 ARCH(1)=0.4

Table 3: Inflation ECM

	Coefficient	t-statistic
Constant	-0.04	-0.47
Δ ms	0.31	0.29
Δ e	1.39***	3.08
Δ Y*	0.61	-0.62
Δ Gp*	0.82***	2.21
$\varepsilon\pi_{-1}$	-0.64***	-3.36
	**5% ***1%	AdjR^2=0.41 DW=2.23 ARCH(1)=-0.7

Table 4: Derived Inflation Effects

	Coefficient	t-statistic
Constant	3.66	0.46
ms	0.81	0.29
e	-0.64**	1.91
y	0.24	0.49
gp	0.49**	1.86
	**5% ***1%	

Table 5: Stationarity Analysis

	DF -1.95<t<0 DW(1.217,1.322)	DFc -3.00<t<0 F<5.18	DFt -3.60<t<0 F<5.68	ADF -3.60<t<0 F<7.24	ADF(2) -3.6<t<0 F<7.24	PERON (a_1-1)/se tp=-3.76
lnQs	ARCH(1)=3.73	ARCH(1)=2. 67	F=20.06	F=174.8	t=15.7	tp=-6.36 a1=0.71
P	ARCH(1)=3.21	t=-2.38 F=5.7 ARCH(1)=1. 47 DW=1.82				
Iglobal	t=-0.65 F=0.35 DW=2.71 ARCH(1)=0.522					
Eglobal	t=0.13	t=5.7 F=32.68	F=170.14	t=3.98 F=19.67	t=3.07 F=17.71	a1=0.7 tp=-6.5
e	F=-29.5 t=0.41	DW=1.21 ARCH(1)=2.	DW=1.2 ARCH(1)	F=19.5	F=15.07	tp=0.96 a1=-2.01

		05	=2.24			

Table 6: Stationarity Analysis for Regions

Iafrica	ARCH(1)=8.35	F=38.8	F=43.8	F=214.5 t=0.32	F=488. 7 t=4.22	a1=0.45 tp=-9.39
Eafrica	ARCH(1)=8.38	F=27.4	F=19.6	F=238.8	F=446. 6 T=2.16	a1=0.56 tp=-8.28
Iasia	F=40.3	ARCH(1)=8.29	F=22.2	F=226.5	F=504. 9	a1=0.71 tp=-6.42
Easia	ARCH(1)=3.45	F=66.5 t=7.78	F=19.6	F=33.2	F=446. 2	a1=0.42 tp=-3.87
Ieurope	ARCH(1)=8.68	F=44.8	F=60.3 t=0.35	F=236.3	F=564. 3 t=4.72	a1=0.30 5 tp=- 11.31
Eeurope	ARCH(1)=2.16	F=25.7	F=12.8	F=238.4	F=19.1	a1=0.75 tp=-5.74
Iamericas	DW=3.15 ARCH(1)=10.14	F=72.4	F=73.8	t=0.28	F=4.64	a1=0.22 tp=- 12.41
Eamerica s	F=45.7	ARCH(1)=5.31	F=24.4	F=169.3	F=338. 1	a1=0.55 tp=- 8.418
Ioceania	F=13.3	F=80.9	F=88.6	F=284.3	F=635. 4	a1=0.15 tp=- 13.41
Eoceania	ARCH(1)=3.62	F=28.2	F=14.1	F=153.9	F=256. 5	a1=0.71 tp=-6.34

Table 7: Global Levels Model

	Coefficient	t-statistic
constant	5.44***	22.84
P	0.0275	0.76
Iglobal	-0.028***	-2.96
Eglobal	-0.077***	-8.005
e	-0.17***	-24.37
EG t =-6.35*** DW=2.35	**5% ***1%	AdjR^2=0.87 DW=0.51 ARCH(1)=17.2

ARCH(1)=1.007		

Table 8: Global Output ECM

	Coefficient	t-statistic
Constant	-0.006	-1.838
Δ P	0.718***	24.362
Δ Iglobal	0.0026	0.25
Δ Eglobal	-0.057	-5.765
Δ e	0.331***	4.698
εt_{-1}	-0.299***	-6.241
	**5% ***1%	AdjR^2=0.97 DW=2.28 ARCH(1)=-0.61

Table 9: Global Derived Output Effects

	Coefficient	t-statistic
constant	-1.632*	1.832
P	0.019	0.762
Iglobal	0.008	0.25
Eglobal	-0.0232***	-4.678
e	0.051***	4.604
	**5% ***1%	

Table 10: Africa Levels Model

	Coefficient	t-statistic
constant	5.093***	23.42
P	0.0021	0.059
Iafrica	-0.014**	-2.58
Eafrica	-0.0317***	-7.71
e	-0.1588***	-21.93
EG t =-7.602 DW=2.29 ARCH(1)=1.64	**5% ***1%	AdjR^2 =0.88 DW=0.75 ARCH(1)=5.18

Table 11: Africa Output ECM

	Coefficient	t-statistic
constant	-0.0025	-0.82
Δ P	-0.0076	-0.084
Δ Iafrica	-0.0042	-1.117
Δ Eafrica	-0.0081**	-2.072
Δ e	0.0255	0.333
εt_{-1}	-0.327***	-7.116
	**5% ***1%	AdjR^2=0.16 DW=2.34 ARCH(1)=0.92

Table 12: Africa Derived Output Effects

	Coefficient	t-statistic
constant	-1.666	0.8204
P	-0.0007	0.048
Iafrica	0.0048*	1.025
Eafrica	-0.0103**	-2.001
e	0.0519	0.3335
	**5% ***1%	

Table 13: Asia Levels Model

	Coefficient	t-statistic
constant	4.808***	21.41
P	0.00095	0.024
Iasia	0.029***	5.66
Easia	-0.0058*	-1.271
e	-0.172***	-29.53
EG t =-7.19 DW=2.304 ARCH(1)=0.748	**5% ***1%	AdjR^2 =0.86 DW=2.83 ARCH(1)=8.904

Table 14: Asia Output ECM

	Coefficient	t-statistic
constant	-0.0026	-0.851
Δ P	-0.0094	-0.102
Δ Iasia	0.02005	0.905
Δ Easia	-0.0137	-0.347
Δ e	0.0363	0.473
εt_{-1}	-0.306***	-7.04
	**5% ***1%	AdjR^2=0.15 DW=2.36 ARCH(1)=0.74

Table 15: Asia Derived Output Effects

	Coefficient	t-statistic
constant	-1.4733	0.851
P	-0.00029	0.024
Iasia	-0.00903**	2.894
Easia	0.0017	0.335
e	0.052	0.473
	**5% ***1%	

Table 16: Europe Levels Model

	Coefficient	t-statistic
constant	5.041***	22.59
P	0.0068	0.1856
Ieurope	-0.0036	-0.601
Eeurope	-0.026***	-7.86
e	-0.168***	-24.032
EG t =-7.19 DW=2.25 ARCH(1)=0.36	**5% ***1%	AdjR^2 =0.87 DW=0.64 ARCH(1)=8.67

Table 17: Europe Output ECM

	Coefficient	t-statistic
constant	-0.0024	-0.809
Δ P	-0.0106	-0.117
Δ Ieurope	0.00277	0.751
Δ Eeurope	-0.009**	-2.416
Δ e	0.0256	0.3366
εt_{-1}	-0.306***	-6.843
	**5% ***1%	AdjR^2=0.16 DW=2.35 ARCH(1)=0.915

Table 18: Europe Derived Output Effects

	Coefficient	t-statistic
constant	-1.545	0.801
P	-0.00208	0.099
Ieurope	0.00111	0.469
Eeurope	-0.0079**	2.309
e	0.0516	0.336
	**5% ***1%	

Table 19: Oceania Levels Model

	Coefficient	t-statistic
constant	4.708***	22.356
P	-0.0064*	-1.184
Ioceania	-0.029***	-8.519
Eoceania	0.0622*	1.743
e	-0.161***	-26.213
EG t =-7.028 DW=0.655 ARCH(1)=-1.713	**5% ***1%	AdjR^2 =0.88 DW=2.275 ARCH(1)=1.571

Table 20: Oceania Output ECM

	Coefficient	t-statistic
constant	-0.0023	-0.775
Δ P	0.0032	1.1376
Δ Ioceania	-0.0154***	-4.20008
Δ Eoceania	0.0321	0.358
Δ e	0.0235	0.3157
εt_{-1}	-0.3114***	-6.937
	**5% ***1%	AdjR^2=0.20 DW=2.34 ARCH(1)=0.638

Table 21: Oceania Derived Output Effects

	Coefficient	t-statistic
constant	-1.466	0.774
P	0.002	0.8204
Ioceania	-0.00906***	-3.7671
Eoceania	-0.0194	0.3508
e	0.05	0.3157
	**5% ***1%	

Table 22: Americas Levels Model

	Coefficient	t-statistic
constant	4.6911***	20.554
P	0.0532*	1.374
Iamericas	0.00207	0.286
Eamericas	-0.0224	-5.2053
e	-0.1535***	-23.345
EG t =-6.999 DW=2.35 ARCH(1)=1.99	**5% ***1%	AdjR^2 =0.86 DW=0.64 ARCH(1)=8.57

Table 23: Americas Output ECM

	Coefficient	t-statistic
constant	-0.00287	-0.938
Δ P	0.0108	0.1188
Δ Iamericas	0.0074*	1.9206
Δ Eamericas	0.00239	0.6933
Δ e	0.054	0.7098
εt_{-1}	-0.2876***	-6.7963
	**5% ***1%	$AdjR^2$=0.17 DW=2.34 ARCH(1)=0.677

Table 24: Americas Derived Output Effects

	Coefficient	t-statistic
constant	-1.3494	0.937
P	-0.0153	0.1184
Iamericas	-0.00059	0.2829
Eamericas	0.00644	0.6872
e	0.04417	0.7095
	**5% ***1%	

Table 24: Stationarity Analysis for the Production Function

	DF -1.95<t<0 DW(1.22,1.32)	DFc -3.00<t<0 F<5.18	DFt -3.60<t<0 F<5.68	ADF -3.60<t<0 F<7.24	PERON $(a_1-1)/se$ $t_p=-3.76$
lnG	-1.05				
t	1.1				
F	2.0				
DW	0.01				
ARCH(1)					
lnK	-3.3				
t	0.27				
F	2.0				
DW	0.84				
ARCH(1)					
lnL	-0.95				
t	0.08				
F	2.0				
DW	1.38				
ARCH(1)					
lnE	0.88	-1.38	-2.54	-2.3	a1=0.74
t	0.077	0.12	0.23	1.00	tp=-3.35
F	2.0	2.0	2.00	2.00	
DW	4.59	4.93	6.15	6.5535	
ARCH(1)					
lnr	-0.86	-3.48			
t	0.075	2.00			
F	2.004	1.073			
DW	3.36				
ARCH(1)					
lnw	6.59	0.51			
t		0.26			
F		1.99			
DW		1.62			
ARCH(1)					
lne	-0.38	-1.47	-1.33	-3.8	a1=0.93
t	0.14	2.16	1.46	5.76	tp=-1.46
F	1.99	1.99	1.99	2.00	
DW	6.7	6.72	7.4	6.65	
ARCH(1)					

Table 26: KL and KLE Production Functions

lnY	KL	KLE	ΔKL	ΔKLE
constant (SE)	5.19*** (0.43)	13.44*** (0.66)	0.002 (0.002)	0.02*** (0.004)
lnK	-1.56*** (0.14)	-0.001 (0.15)	0.07 (0.10)	-0.13 (0.09)
lnL	-0.02 (0.06)	-0.018 (0.04)	0.001 (0.05)	0.64*** (0.10)
lnE		-2.67*** (0.19)		0.28*** (0.07)
R^2 DW ARCH F AIC EG	.596 1.99 9.01* -57.1 -0.28	.84 1.99 10.08* -174.4 -0.38	.003 2.00 0.022 -269.8	.008 2.00 0.15 -268.5

Table 27: Translog KLE Production Function

lnY	Level	Difference	ECM
Constant	-501.2*** (103.8)	-0.002 (0.004)	175.65 (476.14)
lnK	-30.74 (30.66)	0.08 (0.11)	10.77 (20.56)
lnL	28.38** (8.38)	-0.002 (0.05)	-9.94 (-85.29)
lnE	231.92*** (55.59)	-0.44 (0.46)	-81.27 (-73.54)
$(lnK)^2$	0.98 (3.96)	-2.57 (2.72)	-0.34 (-2.01)
$(lnL)^2$	-0.96* (0.42)	0..01 (0.65)	0.34 (1.58)
$(lnE)^2$	-26.7*** (8.13)	34.05 (38.8)	9.36 (28.27)
lnK lnL	1.02 (1.72)	1.46 (2.18)	-0.36 (-0.65)
lnK lnE	5.52 (9.87)	-7.21 (21.5)	-1.94 (-6.21)
lnL lnE	-5.66** (2.10)	-5.13 (8.04)	1.98 (1.65)
Res			-0.35*** (0.08)
R^2 DW ARCH F EG	.87 1.99 10.26* -0.46	.04 2.04 -0.13	.17 2.00 -0.34

Table 28: Symmetric Hessian Matrix

Translog KLE	. .	-13.71 -0.87	0.54 .	0.54 0.02
Translog KLE	-13.71 0.87	1.42 0.01	-0.06 .	-0.06 .
Translog KLE	0.54 .	-0.06 .	. .	. .
Translog KLE	0.55 0.02	-0.06 .	. .	. .

Table 29: Inverse Matrix

Translog KLE	-6 87	21 -515	170 - 4136
Translog KLE	21 -515	4588 20217	3982 -970
Translog KLE	170 -4136	3982 -970	-327 2044

Table 30: Cross and Own Price Substitution Elasticities

ε		K	L	E
r	Translog KLE	-0.03 -0.001	0.13 0.2	0.13 0.2
w	Translog KLE	0.28 0.006	-0.12 -0.99	0.12 0.006
e	Translog KLE	0.99 0.79	0.99 0.79	-0.01 -0.21

Figure 1: Aggregate Demand-Aggregate Supply Curve

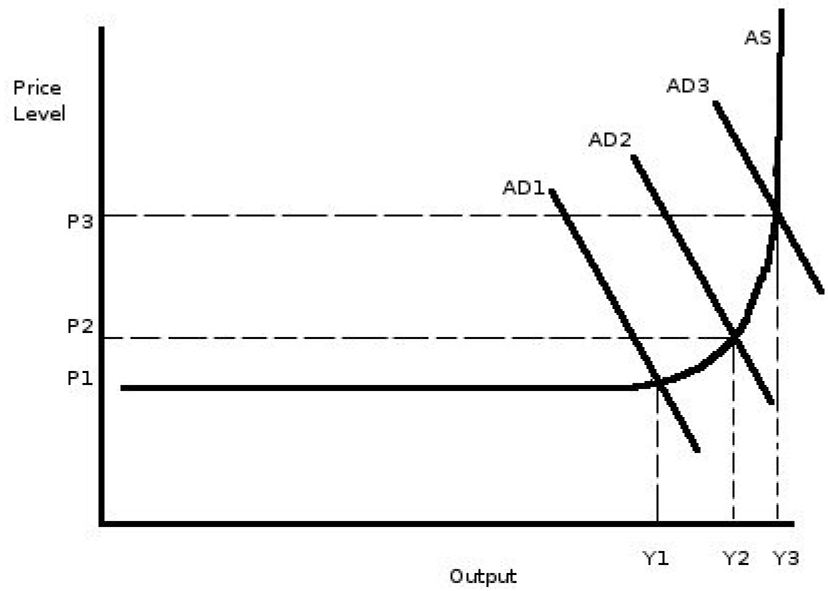


Figure 2: Variable Series

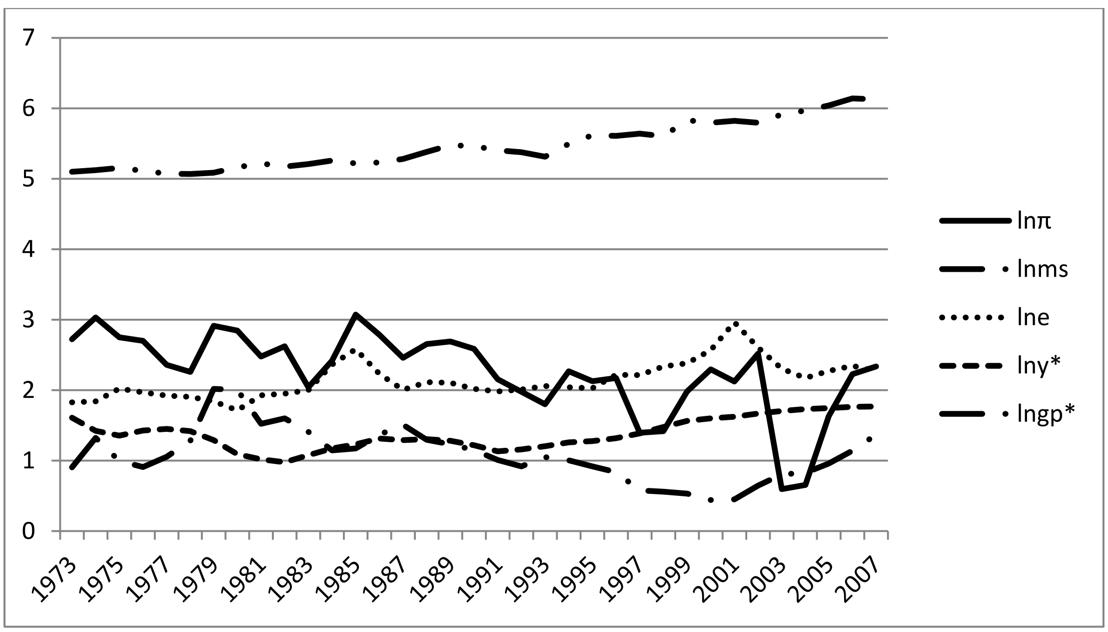


Figure 3: Differences of Variables

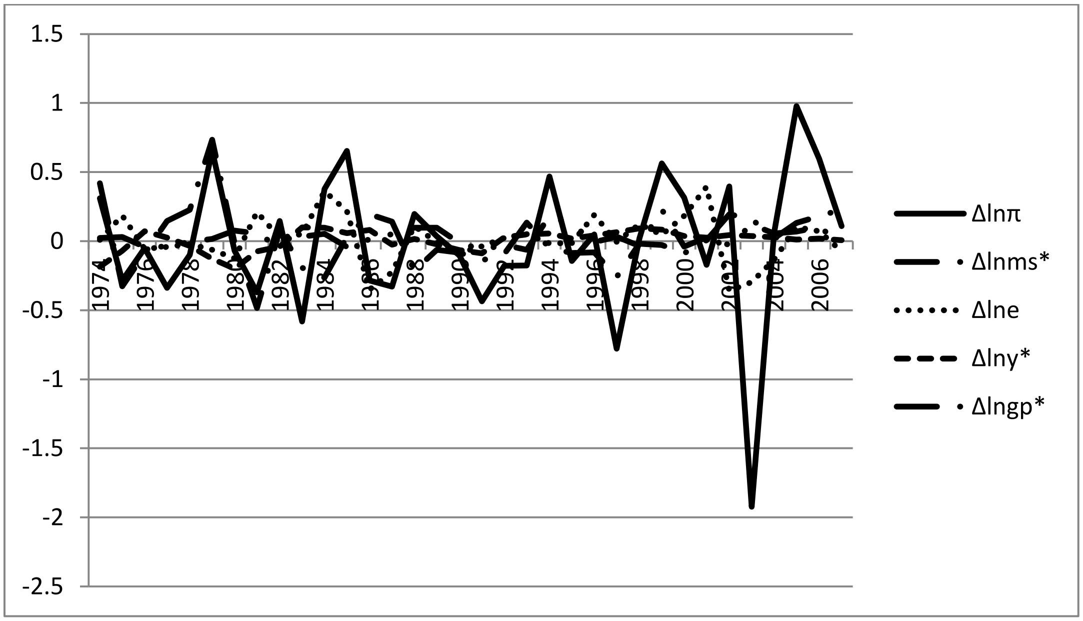


Figure 4: Predicted and Actual Change in Inflation

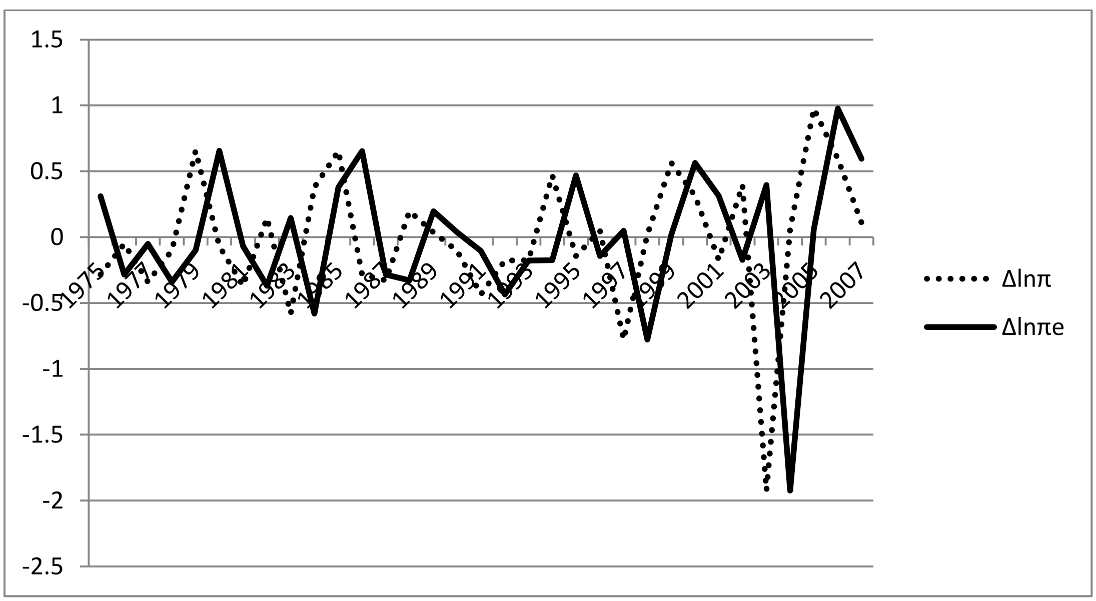


Figure 5: Predicted and Actual Inflation

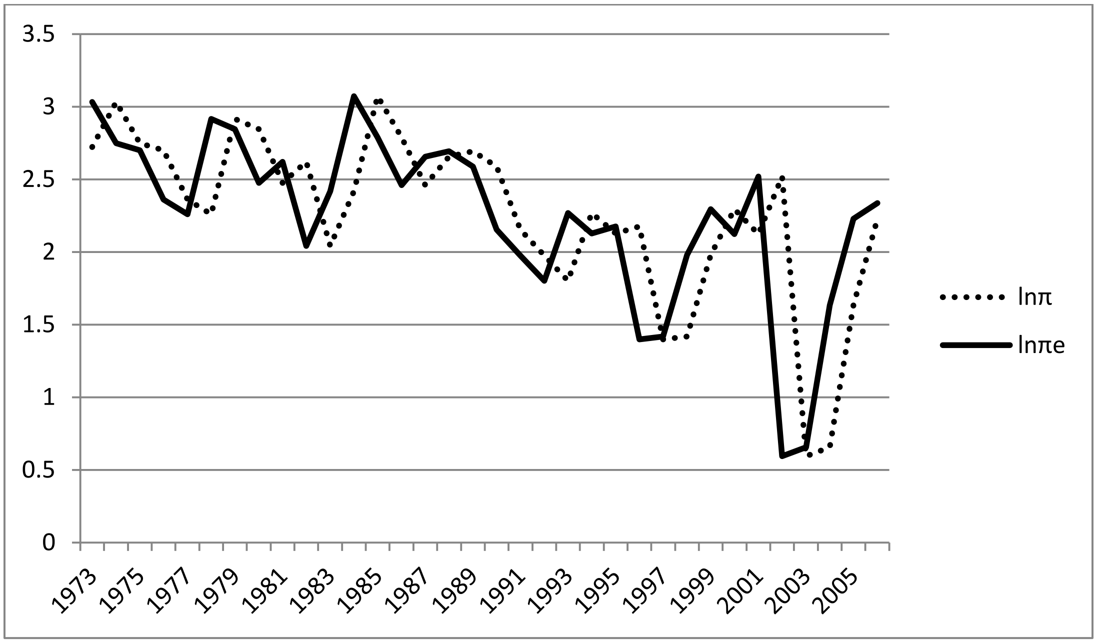


Figure 6: Africa immigration by country

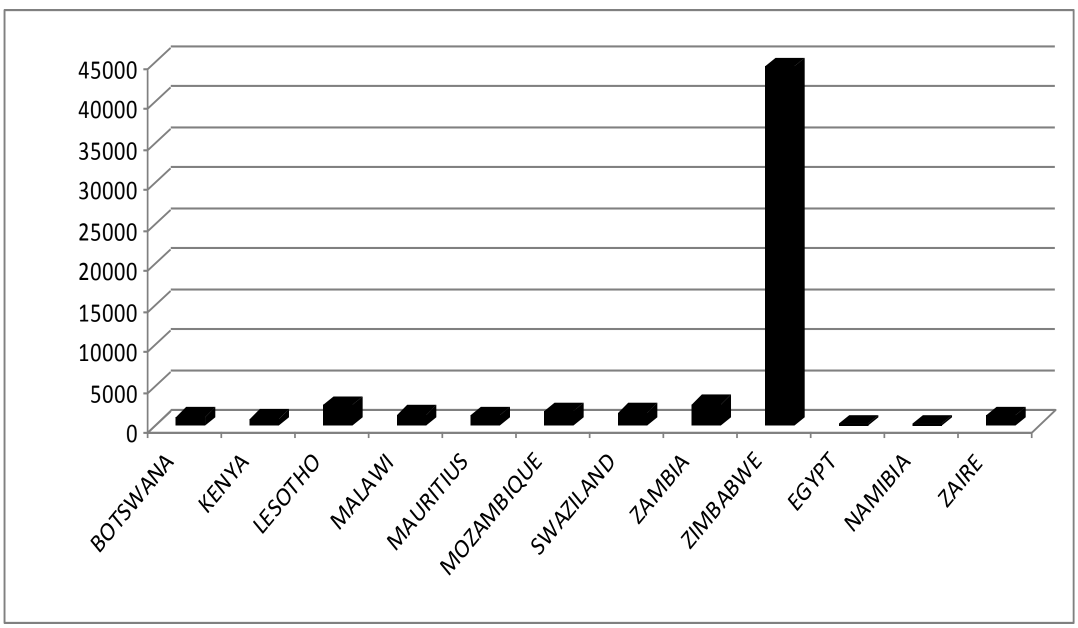


Figure 7: Africa Emigration by Country

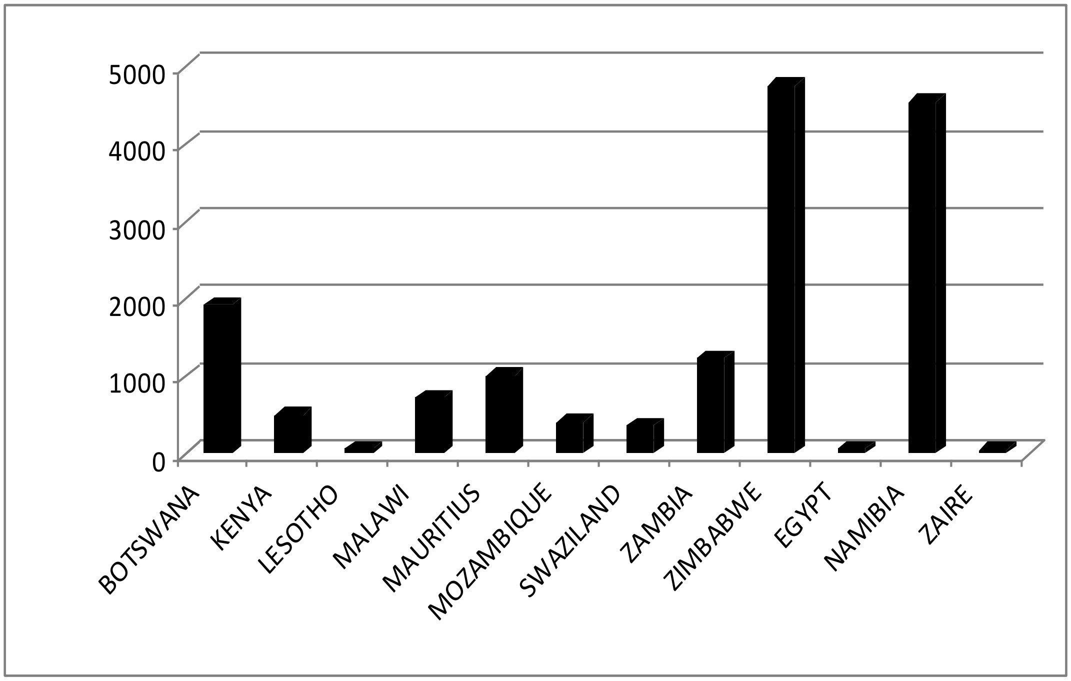


Figure 8: Asia Immigration by Country

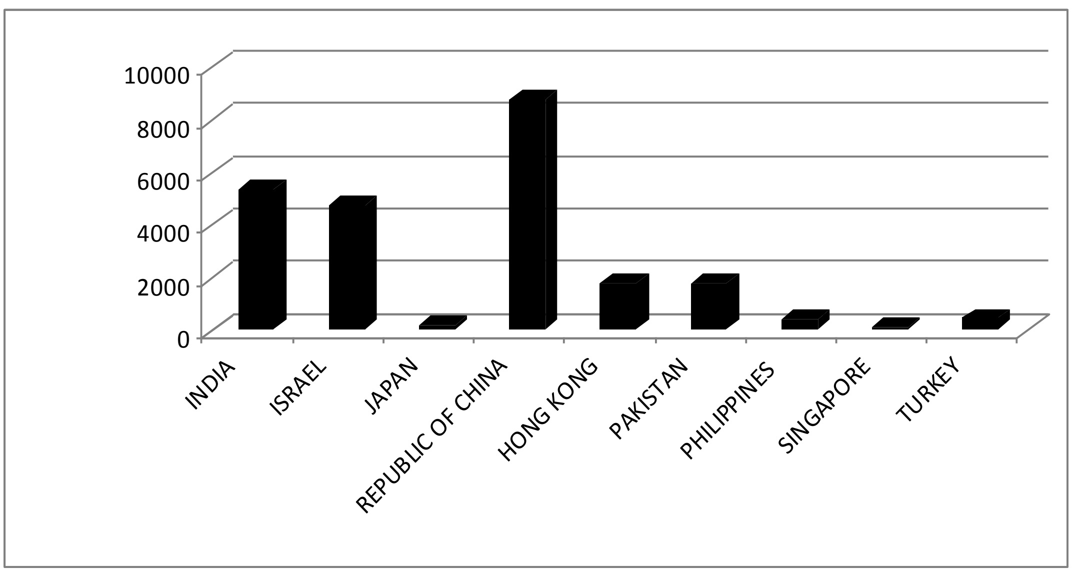


Figure 9: Asia Emigration by Country

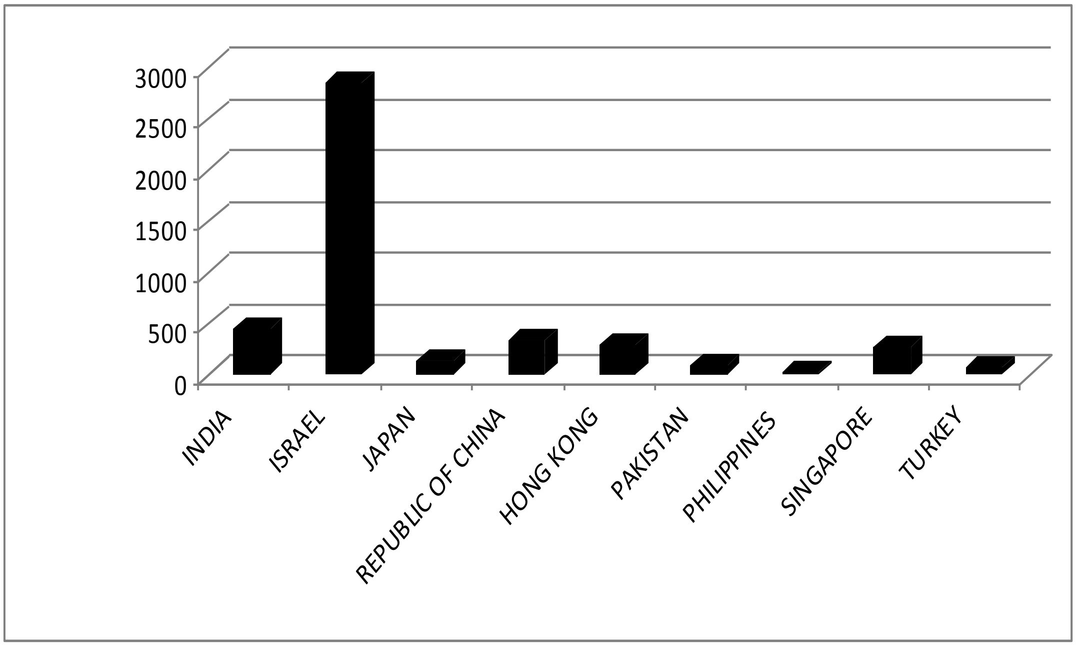


Figure 10: Europe Immigration by Country

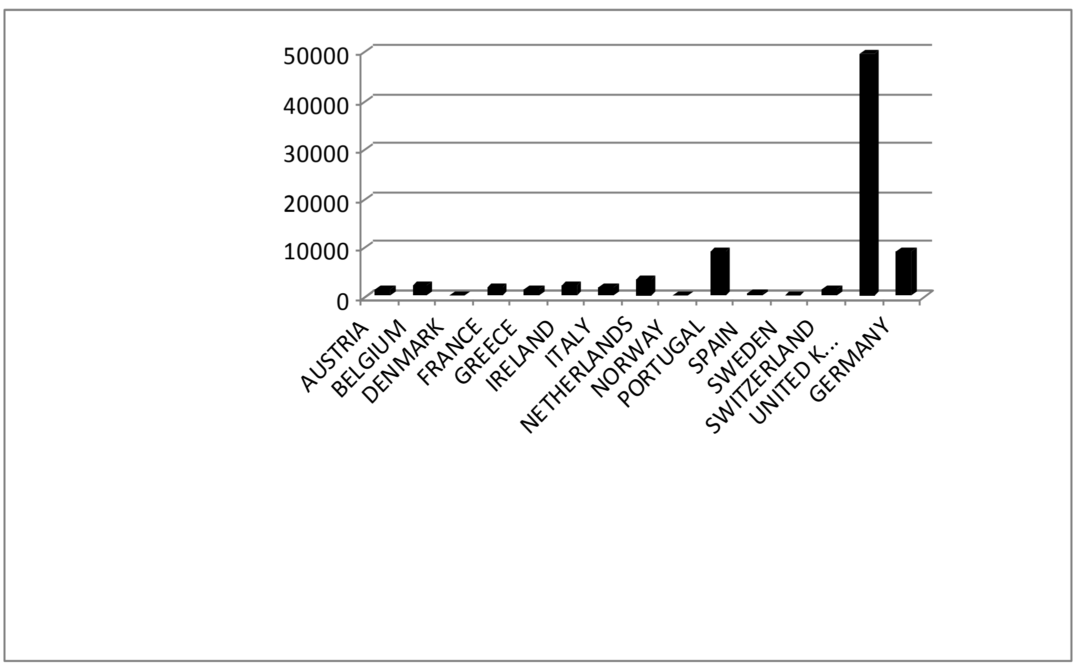


Figure 11: Europe Emigration by Country

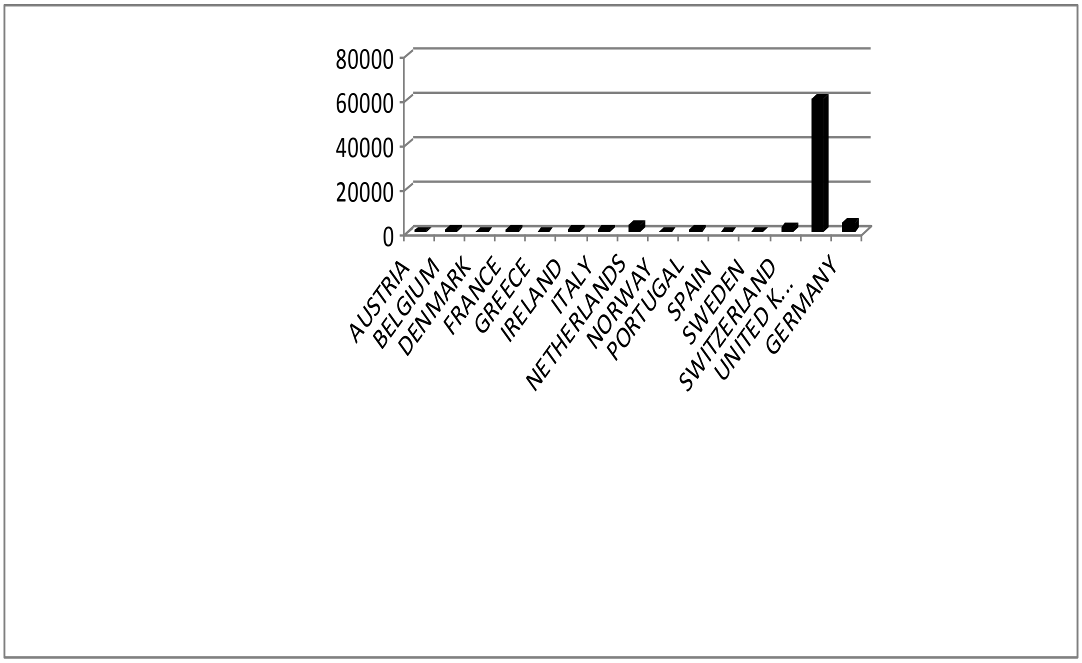


Figure 12: America's Immigration by Country

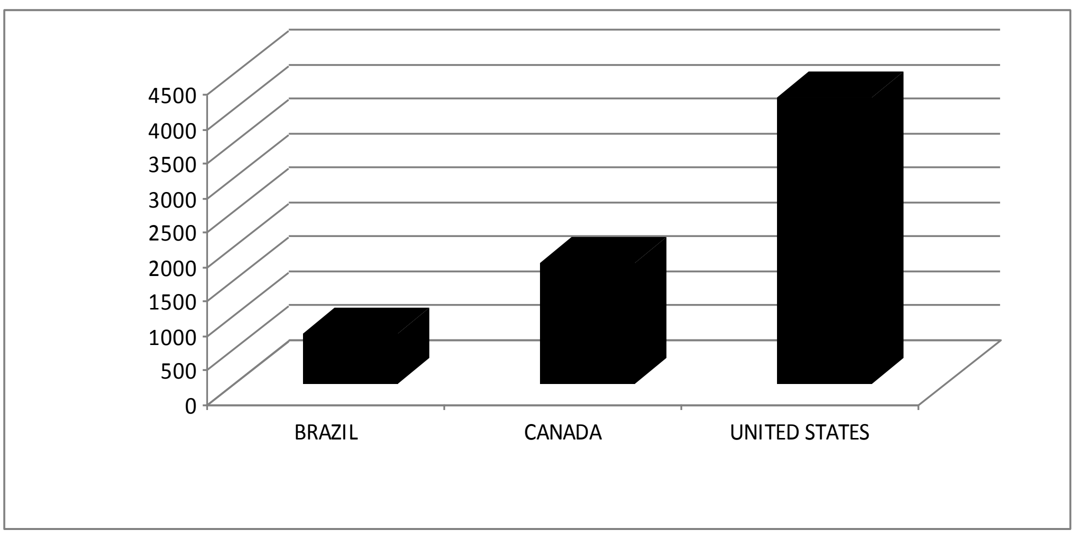


Figure 13: America’s Emigration by Country

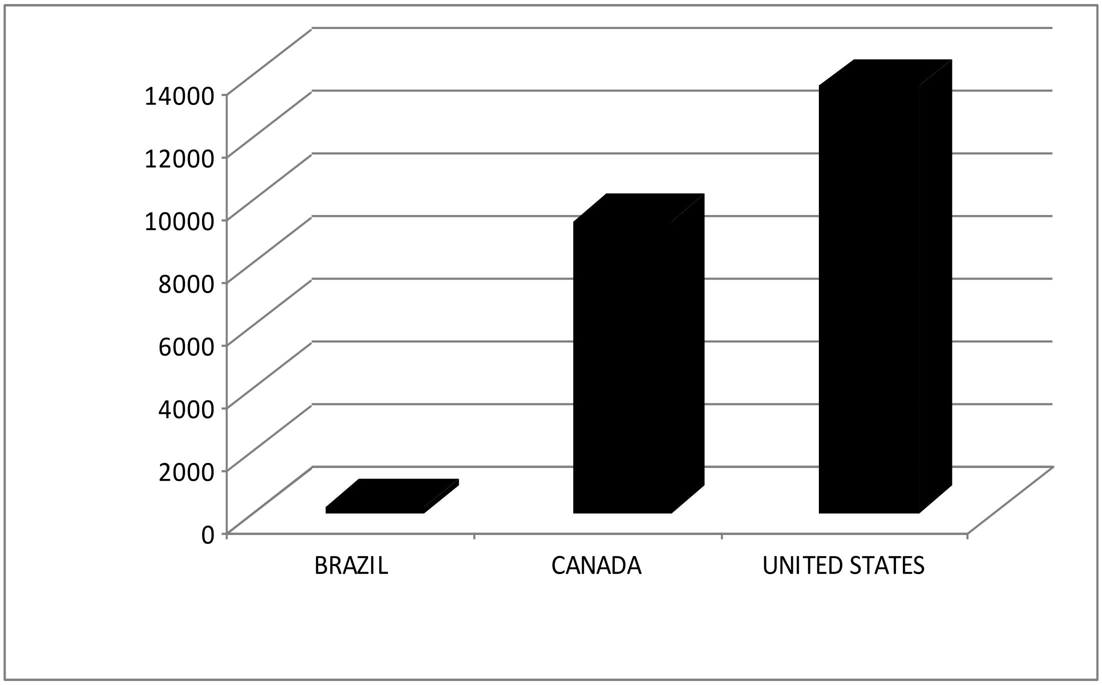


Figure 14: Oceania Immigration by Country

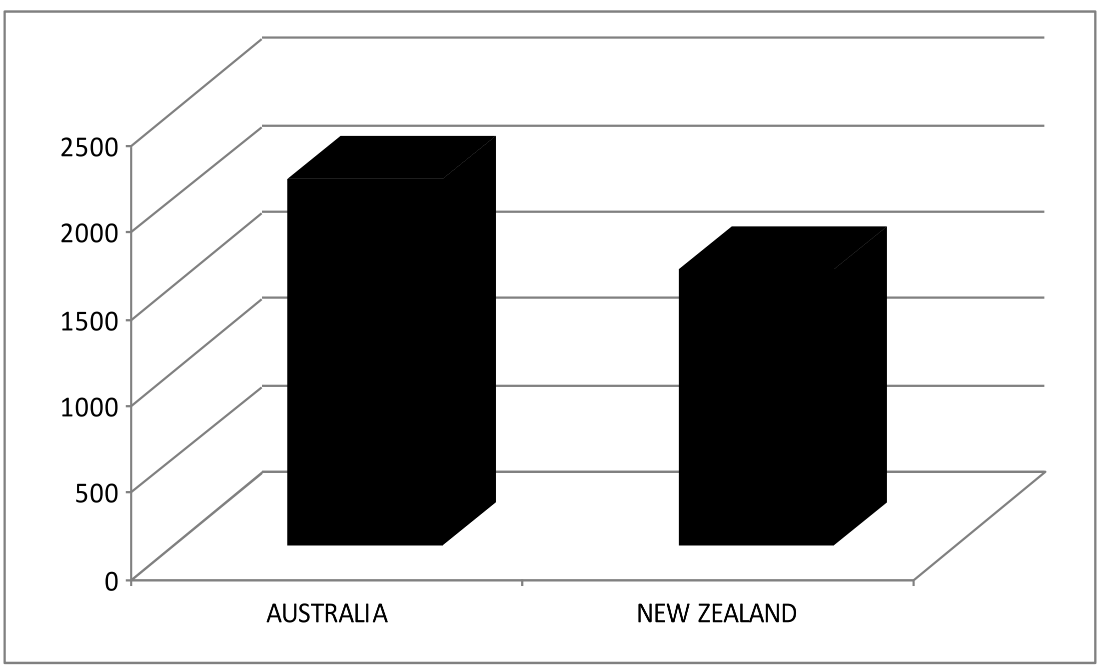


Figure 15: Oceania Emigration by Country

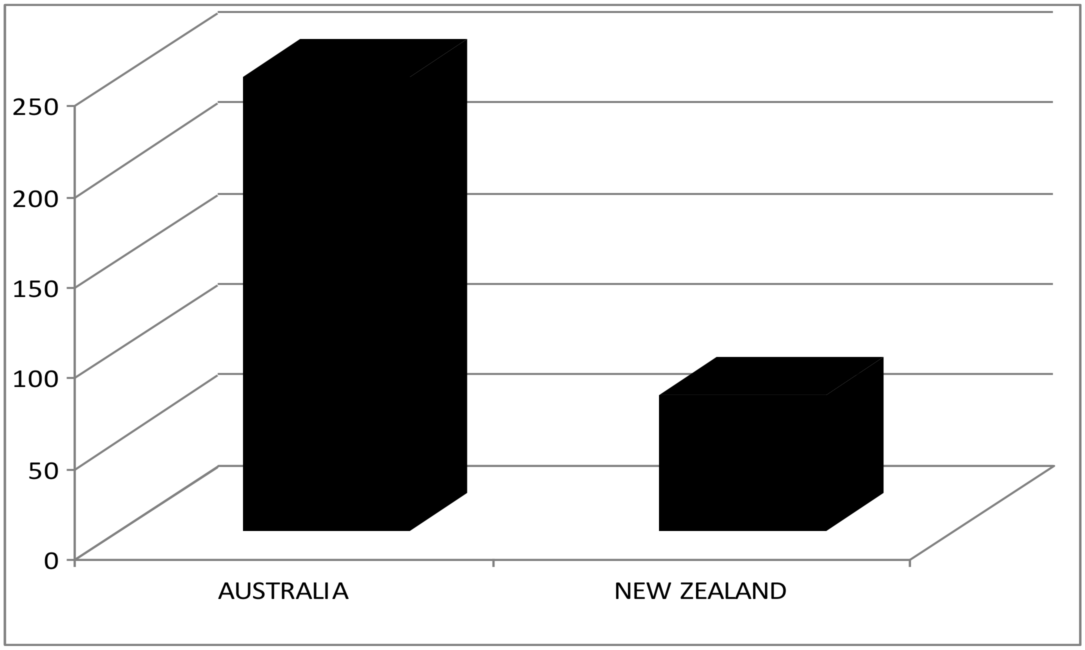


Figure 16: Global Migration in Levels

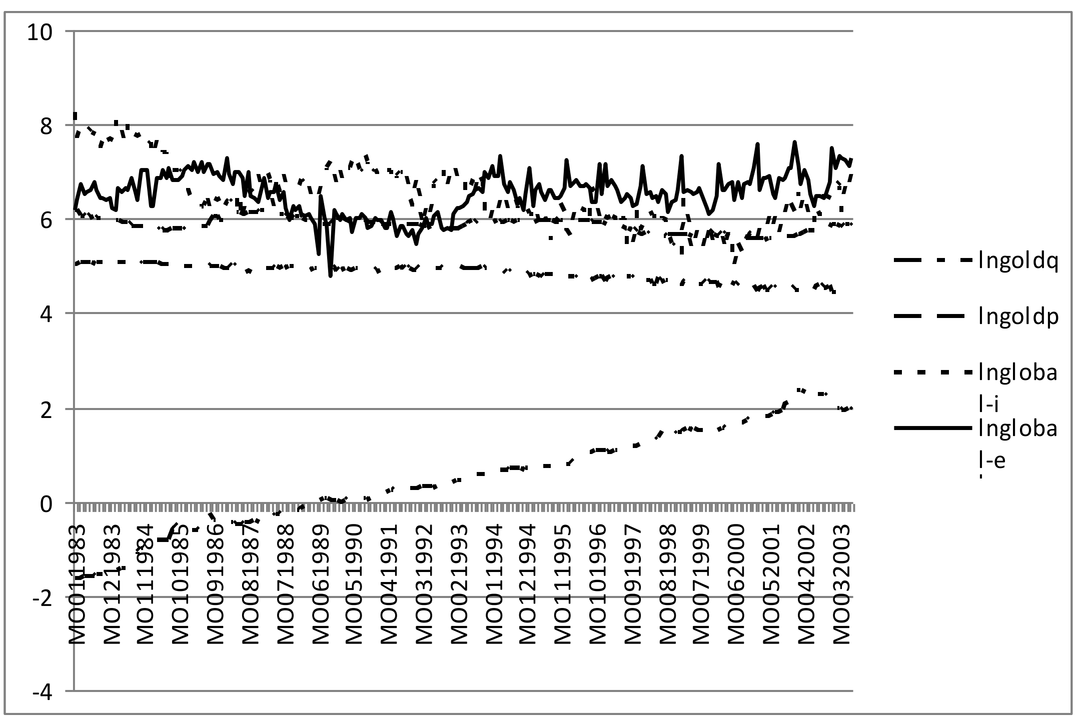


Figure 17: Global Migration in Differences

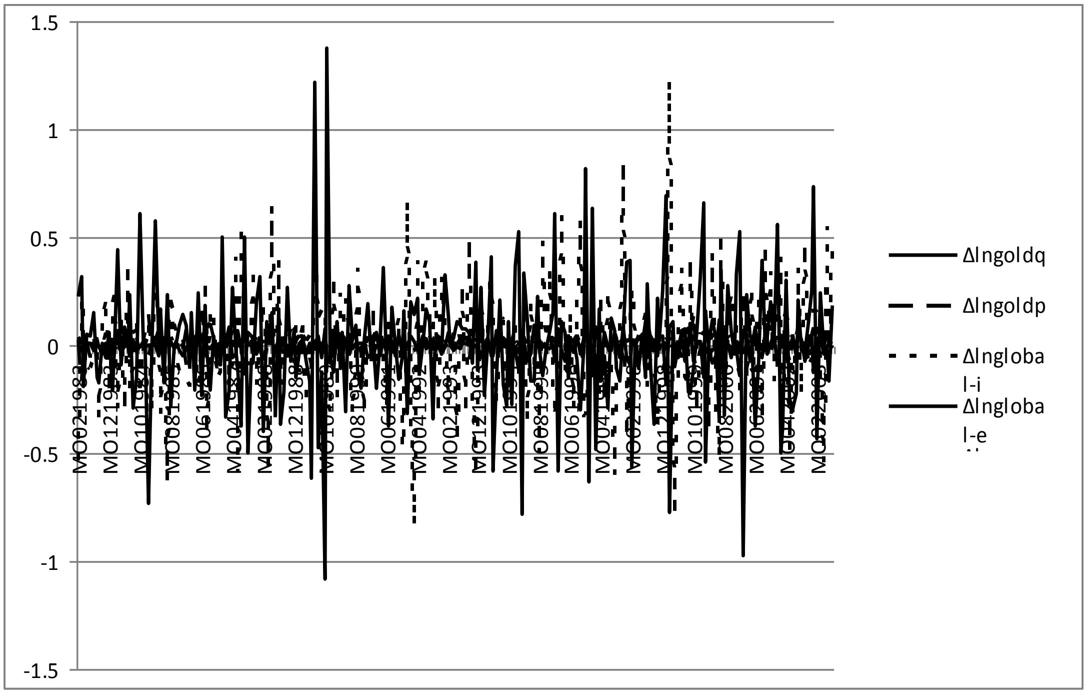


Figure 18: Africa Migration in Levels

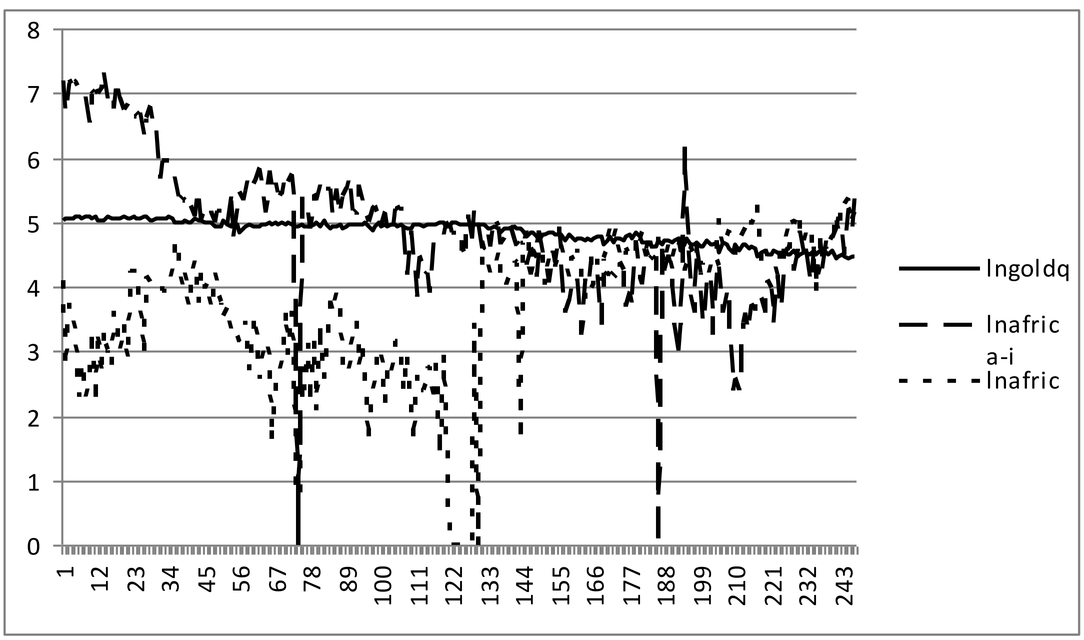


Figure 19: Africa Migration in Differences

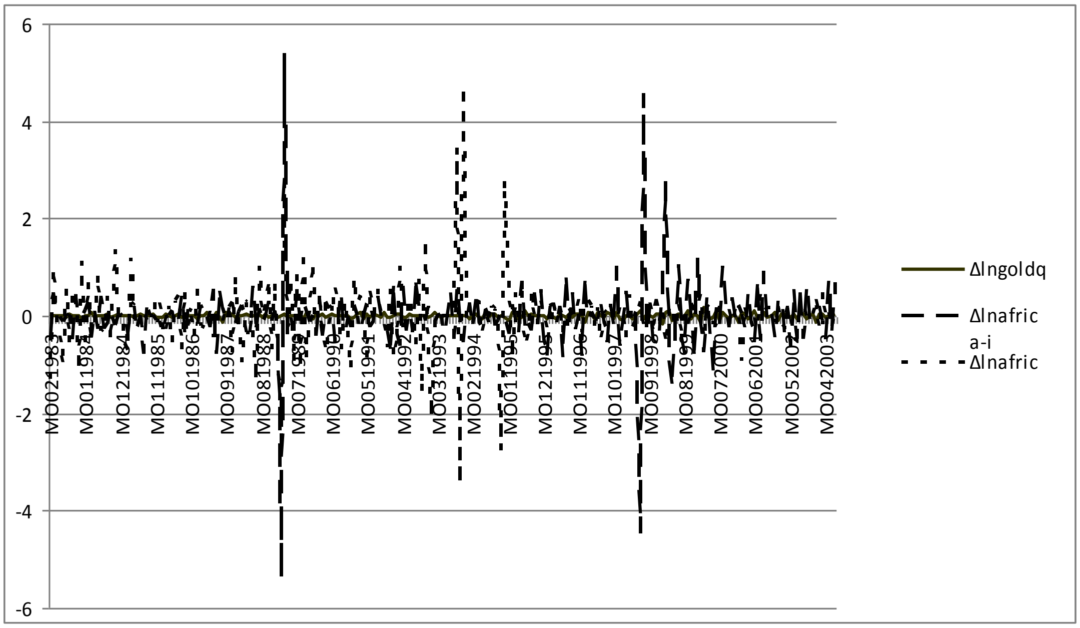


Figure 20: Asia Migration in Levels

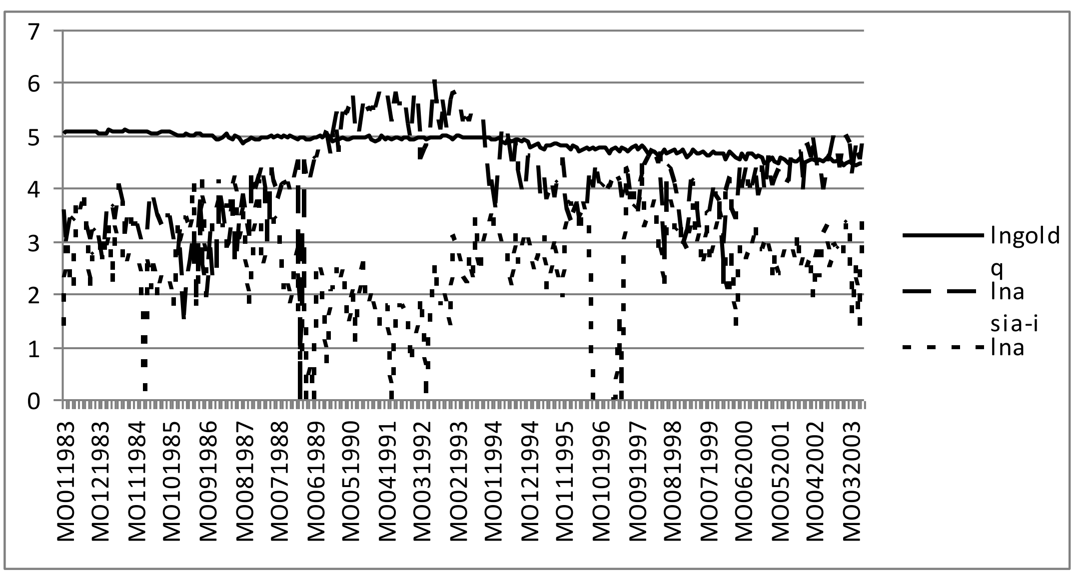


Figure 21: Asia Migration in Differences

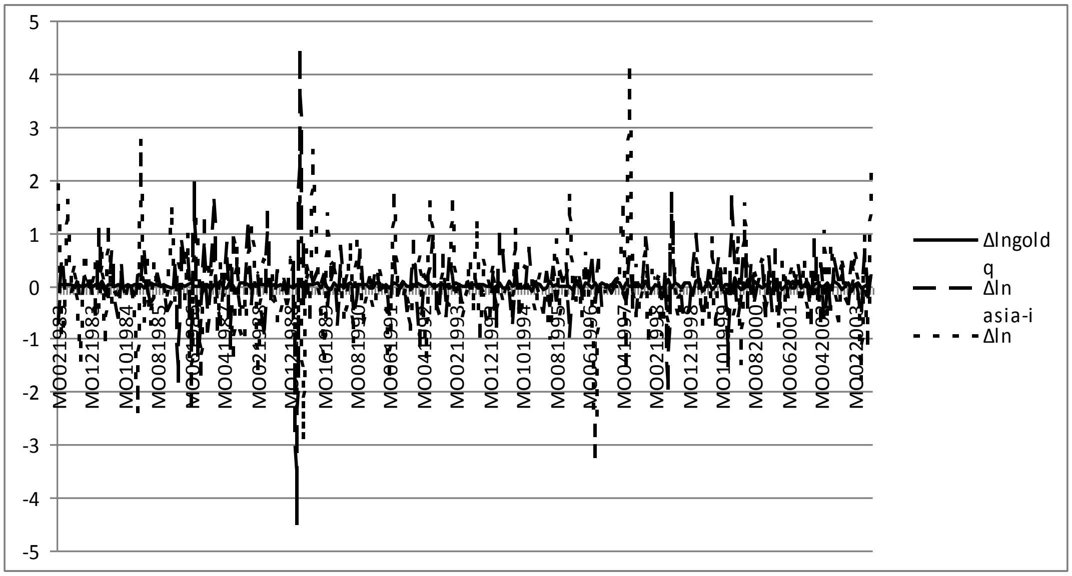


Figure 22: Europe Migration in Levels

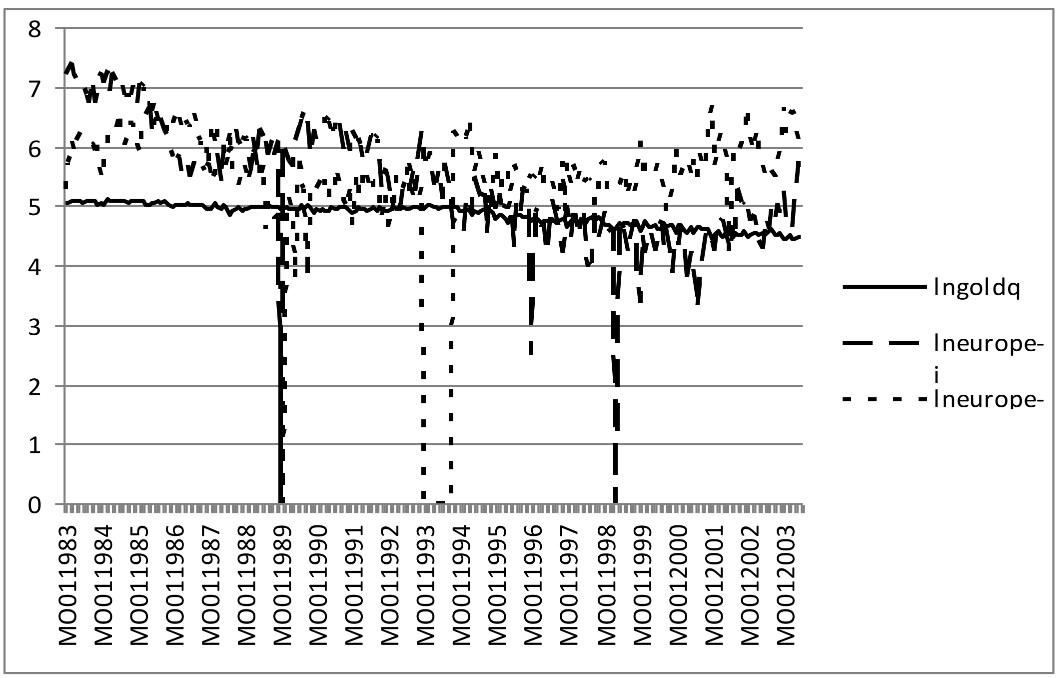


Figure 23: Europe Migration in Differences

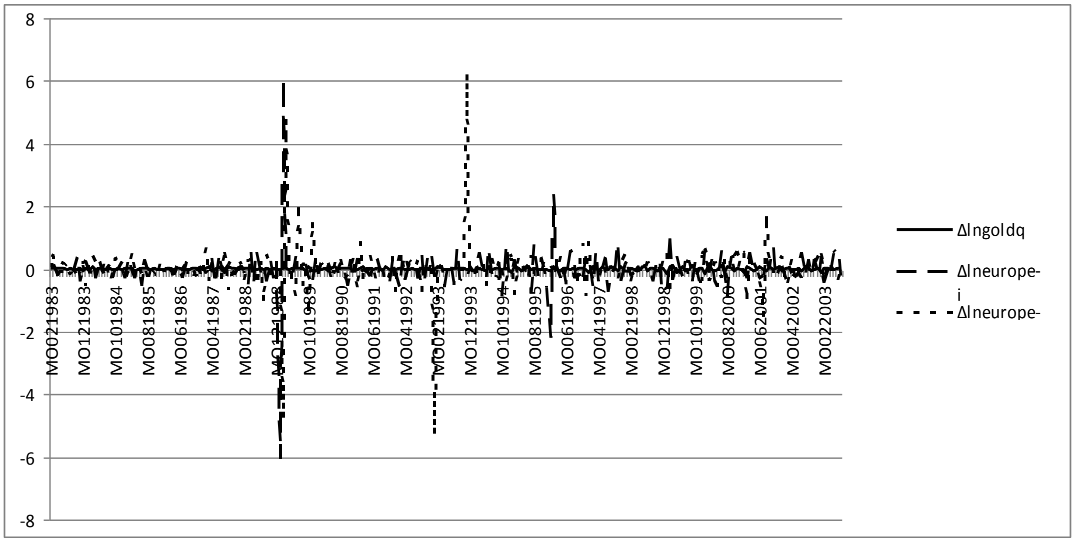


Figure 24: Americas Migration in Levels

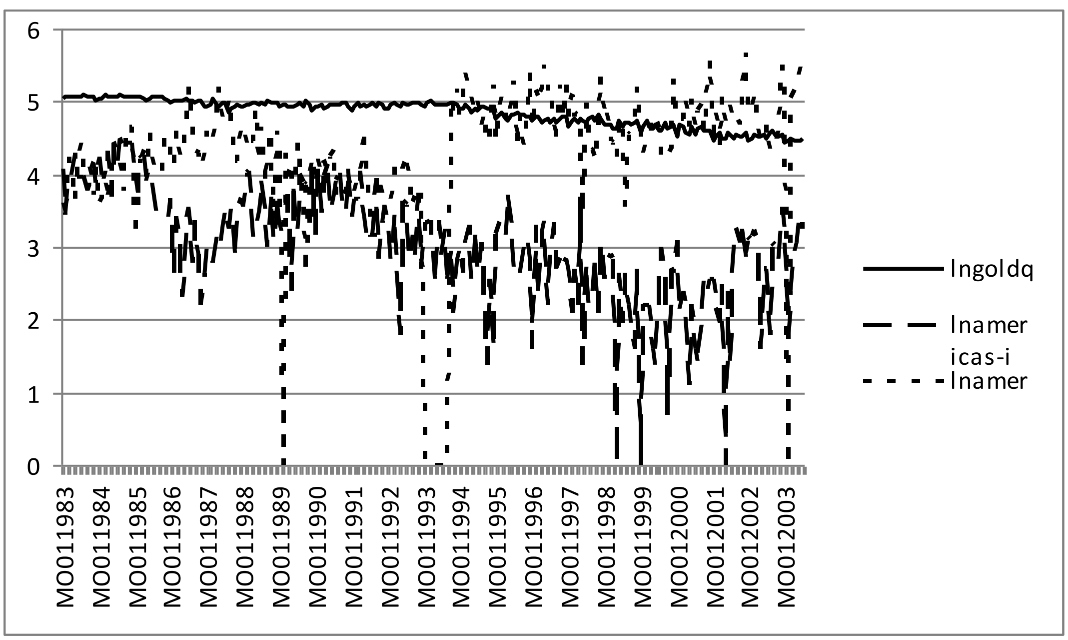


Figure 25: Americas Migration in Differences

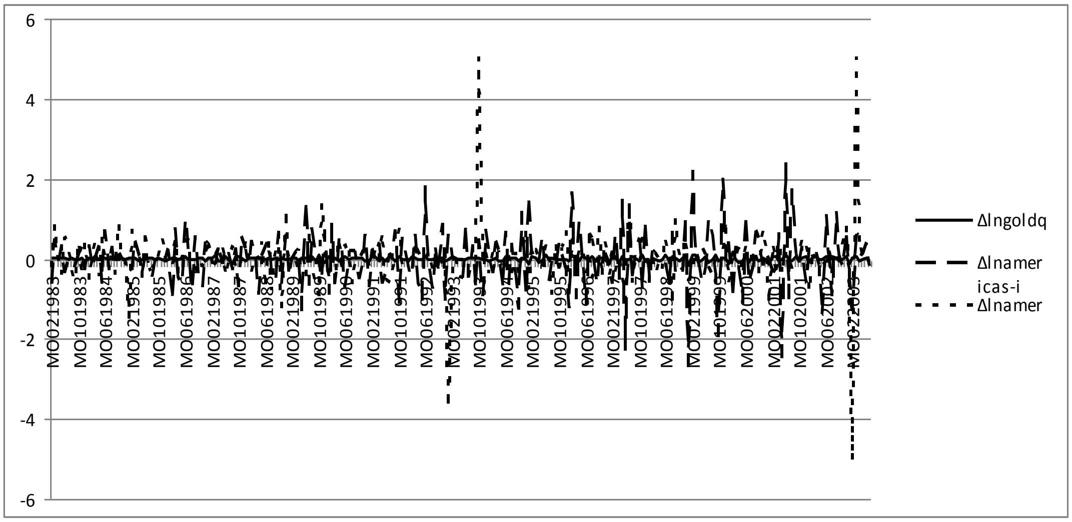


Figure 26: Oceania Migration in Levels

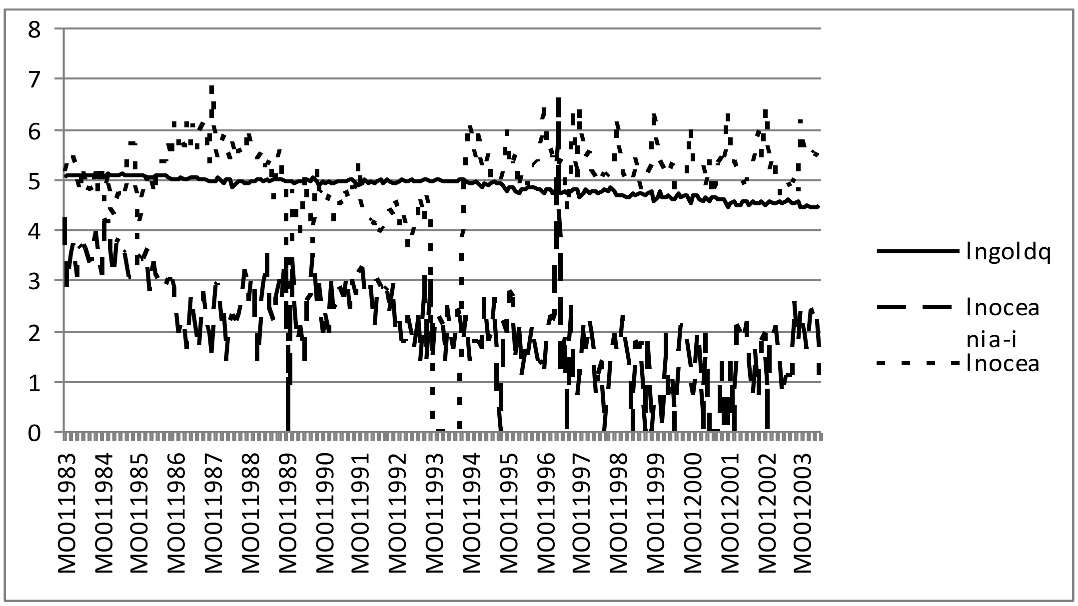


Figure 27: Oceania Migration in Differences

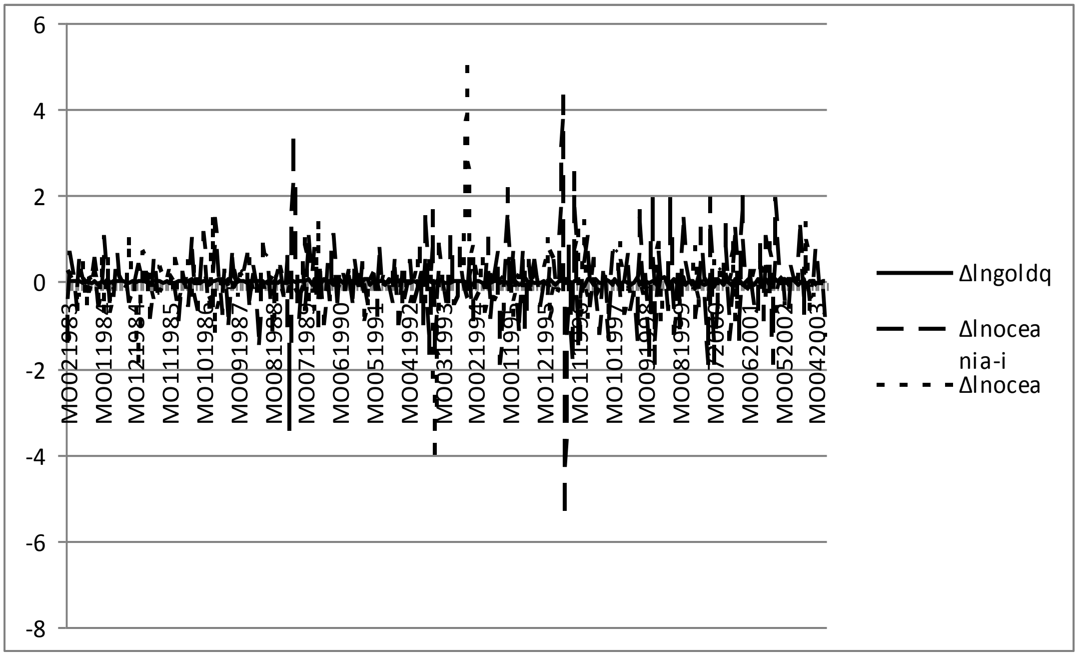


Figure 28: Gold Prices in Levels

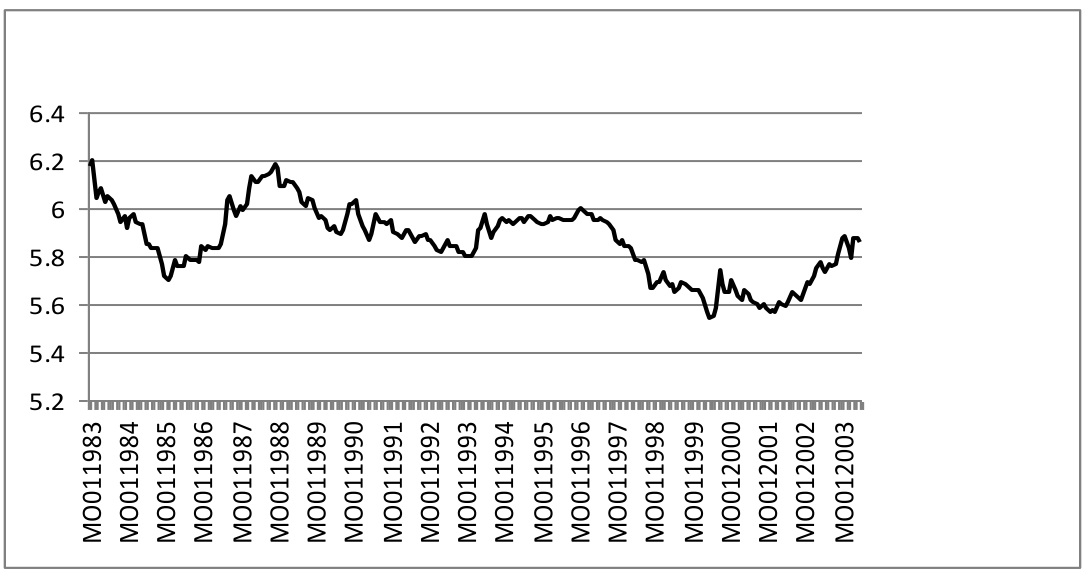


Figure 29: Gold Prices in Differences

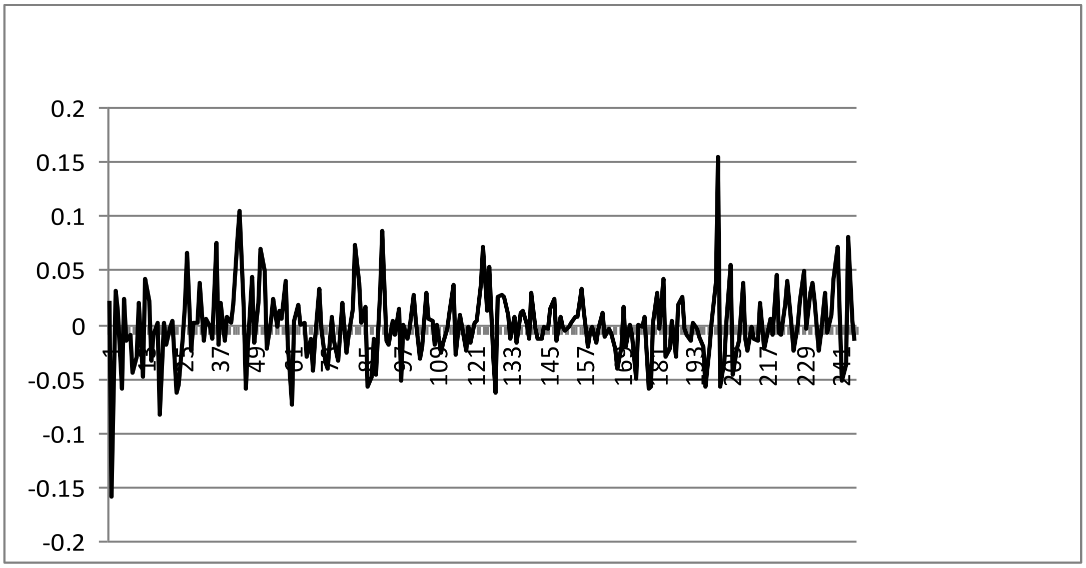


Figure 30: Real Effective Exchange Rates in Levels

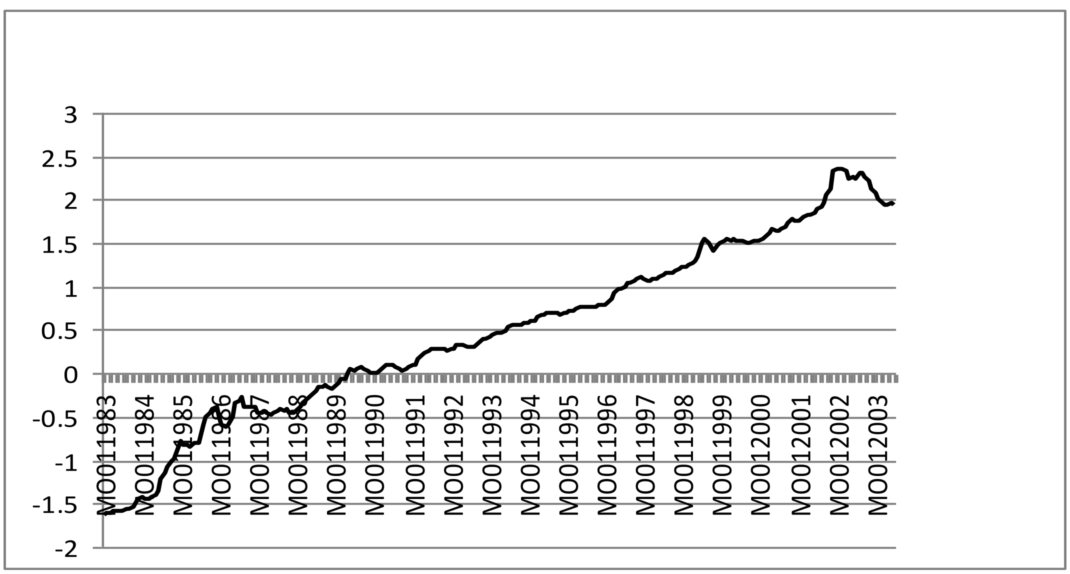


Figure 31: Real Effective Exchange Rates in Differences

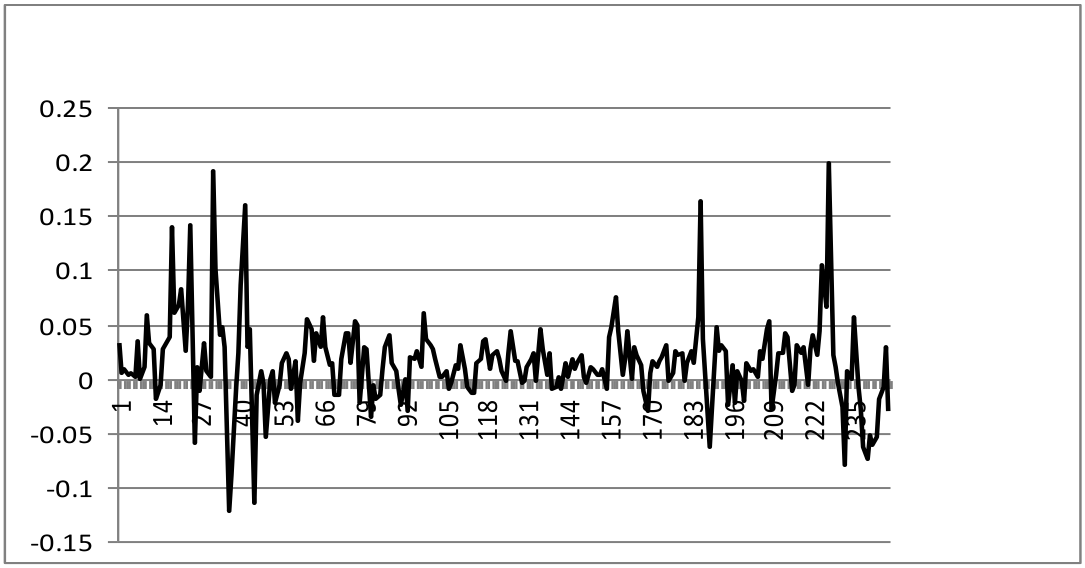


Figure 32: Trends in Output and Inputs

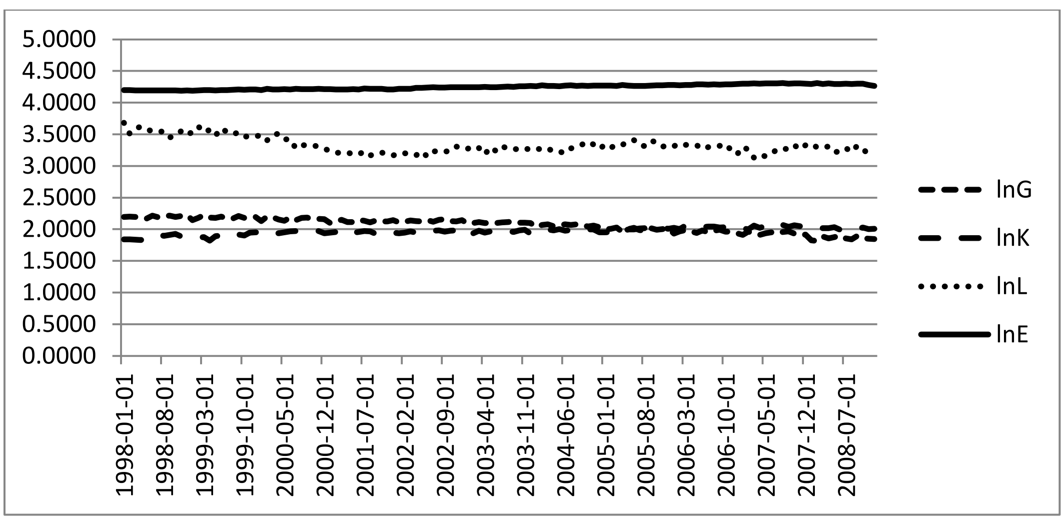


Figure 33: Differences in Output and Inputs

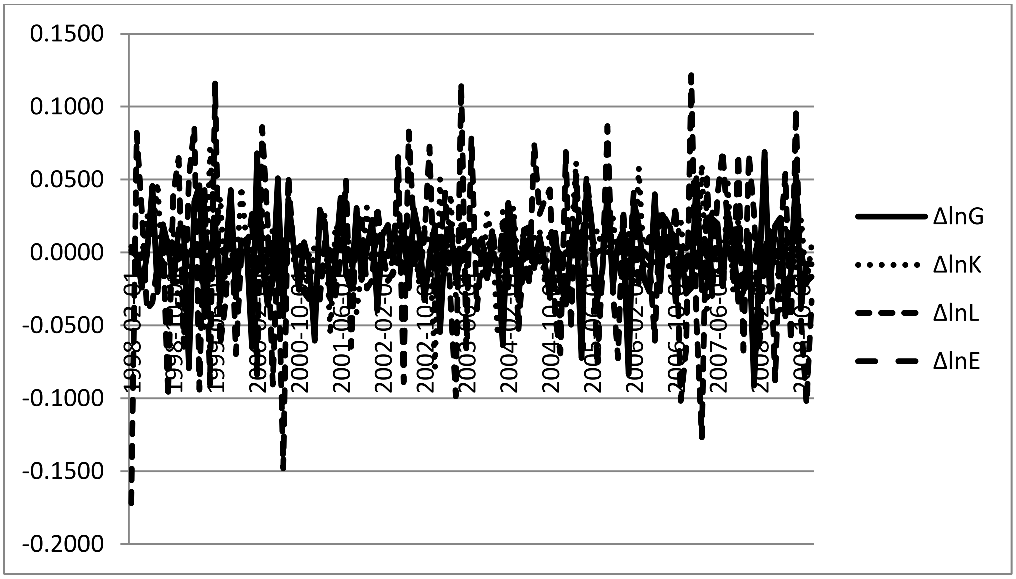
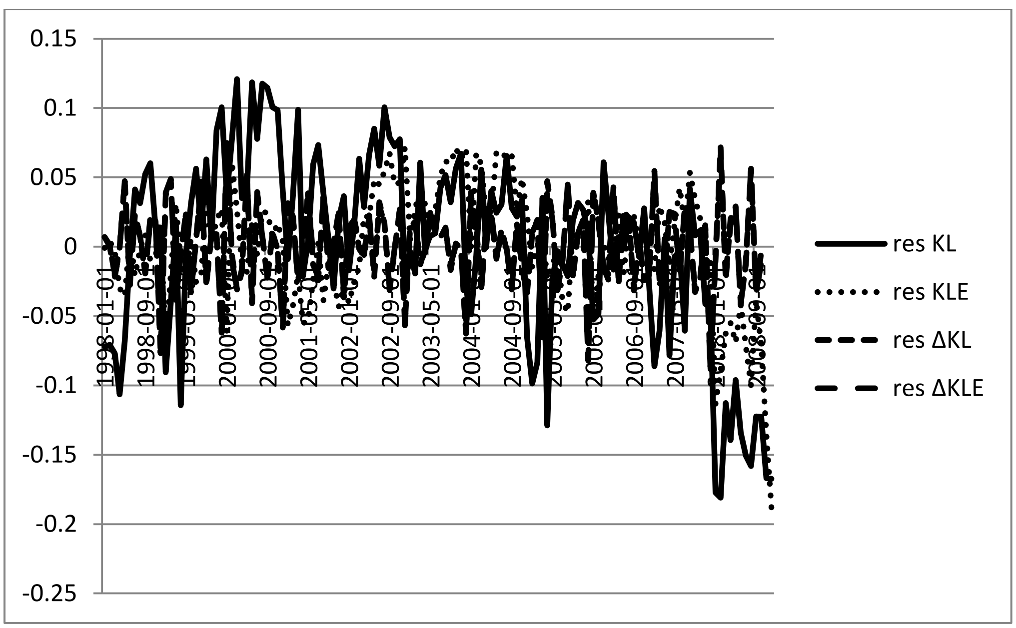


Figure 34: Residuals of KLE and KL Production Functions



References

Afekeina Jerome (2004) A survey of Macroeconomic Models for Policy Analysis and Forecasting in South Africa , National Institute for Economic Policy (working paper) www.niep.org.za

Berg J. Elliot (1961) Backward-Sloping Labor Supply Functions in Dual Economies—the Africa Case, the Quarterly Journal of Economics. Vol 75, No. 3 (Aug., 1961), pp. 468-492.

Borjas J. George (1994), the Economics of Immigration, Journal of Economic Literature Vol. XXXII (December 1994), pp. 1667-1717.

Christiansen E. Robert and Kydd G. Jonathan (1983), The Return of Malawian Labor from South Africa and Zimbabwe , The Journal of Modern African Studies, Vol. 21, No. 2(June, 1983), pp. 311-326.

Crush Jonathan (1988), Tin, Time, and Space in the Valley of Heaven , Transactions of the Institute of British Geographers, New Series, Vol. 13, No. 2 (1988), pp211-221.

Chung Jae Wan (1994) Utility and Production Functions Theory and Applications, Blackwell Publishers. ISBN 1-55786-417-9

Edwards D.P. and Phillips WGB (1976) Metal Prices as a Function of Ore Grade, Resources Policy September 1976, Johns Hopkins University Press.

Fetcher-Spalding Randall and Matibe Khorommbi David (2003) Electricity and externalities in South Africa, Energy Policy 31, 721-734.

Gerber James (2005), International Economics, 3rd Edition, ISBN: 0-321-23796

Gibbon Peter (2001) Upgrading Primary Production: A Global Commodity Chain Approach. World Develop Vol. 29, No. 2, pp. 345-363.

Hartland Penelope (1953), Private Enterprise and International Capital, the Canadian Journal of Economics and Political Science/ Revue Canadienne d'Economique et de Science Politique, Vol. 19 No. 1 (Feb., 1953), pp 70-80.

H.S. Houthakker and Stephen P. Magee (1969), Income and Price Elasticities in the World Trade, The review of Economics and Statistics, Vol. L1 No. 2.

Janine Aaron, John Muellbauer and Benjamin W. Smit (2004), Modeling the Inflation Process in South Africa , South Africa Reserve Bank JEL codes: C22, C32, C51, C52, E31, E52

Janine Aaron and John Muellbauer (2000), Estimating Monetary Policy Rules for South Africa Central Bank of Chile Working Papers No. 89.

Janine Aaron, Ibrahim Elbadawi and Brian Kahn (1997), Determinants of the Real Exchange Rate in South Africa, WPS/97-16

JM Geyser and GA Lowies (2001), The Impact of Inflation and Stock Prices in two SADC Countries; Meditari Accountancy Research volume 9, p 109-122

Kilby Peter (1961) African Labor Productivity Reconsidered, the Economic Journal, Vol. 71, No. 282 (June 1961), pp. 273-291.

Krugman R. Paul and Obstfeld Maurice (2000), International Economics, Theory and Practice, 5th Edition, ISBN: 0-321-03387-6.

Lawrence Edwards, (2004) Exchange Rate Depreciation and the Trade Balance in South Africa (working paper), School of Economics, University of Cape Town.

Lawrence Edwards and Phil Alves (2005), South Africa's Export Performance: Determinants of Export Supply. Africa Region Working Paper Series No. 95, School of Economics, University of Cape Town.

Letsoalo Anthony, Blignaut James, Theun de Wet, and Martin de Wit (2007) Triple dividends of water consumption charges in South Africa. Water Resources Research, Vol 43.

Ley Eduardo and Boccardo Jessica (2010) the taxation of motor fuel, an international comparison. Policy Research Working Paper, the World Bank.

Liwan Audrey and Lau Evan (2007), Managing Growth: The Role of Export, Inflation and Investment in Three ASEAN Neighboring Countries, Munich Personal RePEc Archive (MPRA) Paper No. 3952, http://mpra.ub.uni-muenchen.de/3952

Lucas E. B. Robert (1987) Emigration to South Africa's Mines , The American Economic Review, Vol. 77, No. 3 (June, 1987), pp. 313-330.

Lucas E. B. Robert (1985) Mines and Migrants in South Africa , The American Economic Review, Vol. 75, No. 5)Dec., 1985), pp 1094-1108.

Markusen R. James, Melvin R. James, Kaempfer H. William, and Maskus E. Keith (1995) International Trade, Theory and Evidence, 1st Edition, ISBN: 0-07-040-447-X.

Michael Bleaney and David Fielding (1999), Exchange Rate Regimes, Inflation and Output Volatility in Developing Countries, Center for Research in Economic Development and International Trade, University of Nottingham, CREDIT Research Paper No. 99/4.

Moolman Elna (2003) An Econometric Analysis of Labor Demand at an Industry Level in South Africa, Trade and Industrial Policy Strategies Working Paper 5-2003.

Mordechai E. Kreinin (1998), International Economics, a Policy Approach, 8th Edition, ISBN: 0-03-024581-8.

Patrick Honohan and Philip R. Lane (2004), Exchange Rates and Inflation under EMU: an Update Economic Policy, http://www.economic-policy.org/commentaries.asp

Prothero R. Mansell (1974) Foreign Migrant Labor for South Africa , International Migration Review, Vol. 8, No. 3, International Migration in Tropical Africa (Autumn, 1974), PP. 383-394.

Robert J. Gordon (1981), Inflation, Flexible Exchange Rates, and the Rate of Unemployment, National Bureau of Economic Research (NBER Working Paper Series), Working Paper No. 708

Salt John (1992) the Future of International Labor Migration, International Migration Review, Vol. 26, No. 4 (winter, 1992), pp. 1077-1111.

Staff (2007), the Mineral Industry of South Africa, South Africa Department of Minerals and Energy.

Taylor John (1990) the Reorganization of Mine Labor Recruitment in Southern Africa: Evidence from Botswana, International Migration Review, Vol. 24, No. 2, Special Issue: Labor Recruiting Organizations in the Developing World (summer, 1990), pp. 250-272.

Thompson Henry (2006) International Economics, Global Markets and Competition, 2nd Edition, ISBN: 981-256-346-6.

Thompson Henry, Victor Ofori-Boadu and Osei Yeboah (2010) Fuel Substitution in US Corn Production in a Translog Cost Error Correction Model, Working Paper, Auburn University.

Thompson Henry (2010) Labor and Energy in a Mechanical Production Function, Working Paper, Auburn University.

Thompson Henry (2007) an Introduction to Time Series Regression, Auburn University.

Toit Du Charlotte and Koekemoer Renee (2002) A Labor Model for South Africa., Resources and Energy 1, 43-56

Van Der Merwe R.J., (2007), Inflation Targeting in South Africa. South Africa Reserve Bank, Occasional Paper No. 19, ISSN: 1811-735X, http://www.reservebank.co.za

Varian Hal (1992) Microeconomic Analysis, 3rd edition, W.W. Norton & Company, Inc. ISBN 0-393-95735-7.

Vusi Gumede (2000), Import Performance and Import Demand Functions for South Africa , Department of Trade and Industry, Republic of South Africa.

Wilson Francis (1976) International Migration in South Africa, International Migration Review, Vol. 10, No. 4(winter, 1976), pp. 451-488.

Wim Naude and Riaan Rossouw (2008) Export Diversification and Specialization in South Africa: Extent and Impact, World Institute for Development Economics Research, Version 22 JEL codes F10, F14, O24, O14, O55.

Yohane Khamfula (2004), Macroeconomic Policies, Shocks and Economic Growth in South Africa, Global Development Network, Working Paper.