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Two Essays on the Long-Run Relationship among Copper Production, Economic Growth, and Energy Consumption: A Case of the Democratic Republic of Congo (DRC)

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Graduate School of Seoul National University

College of Engineering

Technology Management, Economics, and Policy Program

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Abstract

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The mining sector has been the main engine of the Democratic Republic of Congo's (DRC) economy since its independence in 1960. This sector accounted for two-thirds of its exports and 25% of its GDP (World Bank, 2004). The revenues and other benefit streams generated by the sector, however, have not been used in a wise and/or sustainable way, largely due to the key problems with the sector governance. Until now, mining is the country's principal industrial activity.

This dissertation includes two essays. The first essay investigates the long-run relationships among economic growth as measured by the gross domestic product (GDP), energy consumption, copper production, and copper price in the international market for DRC. The annual time series were utilized and spanned the years 1970-2010. The results of the study revealed that there are no long-run relationships among the aforementioned variables but that short-run relationships exist among them.

The cointegration approach was used in this study. The time series properties of the data were analyzed, and a vector autoregressive model with the first difference was used to evaluate the direction of causality among the variables. The key study findings are as follows: bidirectional causality between GDP and energy consumption, unidirectional causality running from GDP to copper production, unidirectional causality running from copper production to energy consumption, and bidirectional causality between copper price and copper production.

From the policy perspective, the confirmation of the feedback hypothesis between economic growth and energy consumption warns against the use of policy instruments geared towards restricting energy consumption as they may lead to adverse effects on economic growth. As the electrification rate in DRC is only 11%, it may not be feasible to reduce the energy consumption. What is needed is to make the electricity sector more efficient so that it could produce a greater output per unit of electricity used. Therefore, emphasis should be placed on supply-side options and energy efficiency than on energy-limiting policies.

The unidirectional causality from copper production to energy consumption is explained by the increased demand for energy from the mining sector, which is energy-intensive. This sector experienced strong and positive growth in the last decade.

Given DRC's extensive dependence on oil product imports for its national needs, to enhance the security of the country's oil supply and to cope with the increase in the demand for energy due to the country's mineral activities, the government should come up with energy policies focusing on reducing the country's dependence on energy imports by prioritizing the development of domestic energy sources. This means increasing power generation by rehabilitating and upgrading the existing equipment and facilities; reinforcing the network; building new hydroelectric plants; promoting wind, solar, and geothermal energy; and pushing forward its on- and off-shore exploration of oil and gas.

The second essay investigated the effectiveness of the drivers for increasing the share of a country's copper production in the international copper market via panel data analysis of a set of 21 countries that spanned 20 years, from 1991 to 2010. The fixed- and random-effects models were used. The determinants were categorized as governance, socioeconomic, and country-specific factors. Variables such as energy consumption, political stability and government effectiveness, and mineral rents are positively significant determinants of increase in market share. Hence, strong and stable political institutions are conditions for market share increase and thus, economic growth. The other variables, such as energy import, foreign direct

investment (net inflow), and industry value added and strength to the investor protection index were not statistically significant.

In terms of policy, governance plays a crucial role in increasing market share. Therefore, successful linkage development will rely on simultaneous multifactor promotion: skills, savings, business performance, government effectiveness, policy making, and implementation capacity. This means building backward and forward linkages, which requires creating a business environment and public-sector institutions that foster growth.

The reform policies of the government should focus on strengthening regulation institutions through capacity building and by ensuring transparency and accountability.

Keywords: Economic growth, copper production, cointegration, mineral and energy policies, institutions, market share, DRC

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THEORETICAL AND EMPIRICAL ISSUES ON COPPER PRODUCTION, ENERGY CONSUMPTION, AND ECONOMIC GROWTH

Chapter 1. Introduction

1.0 Issues and study outline

It is extensively recognized that energy is one of the most important inputs for economic development. Energy drives economic productivity and industrial growth and is central to the operation of any modern economy. It enhances the factors of production and significantly increases the living standards.

The energy crises in the 1970s and the persistently high energy prices, particularly of oil, have had a significant impact on the economic activities of developing economies. This crisis has drawn the interest of a great number of academics, scholars, and practitioners and has led them to investigate the relationship between energy consumption and economic growth using the modern advances in time series econometrics.

Many studies suggest that energy consumption has a high positive correlation with economic growth. Whether economic growth takes precedence over energy consumption or energy consumption boosts economic growth has also been investigated in a number of studies, yet the empirical evidence is mixed and conflicting. The lack of consensus in the empirical results may be attributed to the differences in variable selection, model specifications, time horizon, and econometric approaches employed.

Therefore, the key question in energy economics remains whether economic growth leads to energy consumption or whether energy consumption leads to economic growth. This debate has puzzled economists for years (Georgantopoulos & Tsamis, 2011).

One of the reasons for the disparate and often conflicting empirical findings on the relationship between energy consumption and economic growth lies in the variety of approaches and testing procedures employed in the analysis. Many of the earlier analyses employed simple log-linear models estimated using ordinary least squares (OLS), without any regard for the nature of the time series properties of the variables involved.

As has recently been proven, however, most economic time series are non-stationary in level form (Granger & Newbold, 1974). Thus, the failure to account for such properties can result in misleading relationships among the variables (Asafu-Adjaye, 2000).

Overall, the empirical evidences from the previous studies on this subject show that the causal relationship between energy consumption and economic growth differs from one country to another and over time. Although most of the previous studies found a direct causal relationship between the various proxies of energy consumption and economic growth, the literature regarding the possible neutrality between energy consumption and economic growth is growing in quantity and substance. Examining the energy-economic growth nexus is of great interest mainly due to its far-reaching policy and economic implications (Odiambo, 2009).

The seminal study of Kraft and Kraft (1978), probably motivated by the oil price shock of 1973, explored the relationship between energy consumption and economic growth (i.e., the energy-GDP nexus). Examining the energy-GDP nexus is of interest mainly due to its far-reaching policy implications. The type of relationship can be classified into four testable hypotheses. First, if a unidirectional relationship running from energy consumption to economic growth is found, then the economy is said to be an energy-dependent one, and any energy policy encouraging conservation may adversely affect economic growth. This is known as the *growth hypothesis*. Second, if an inverse relationship is found (i.e., causality running from GDP to energy consumption), then any energy policy will not affect economic growth, but changes in GDP will directly result in changes in energy consumption. This is known as the *conservation hypothesis*. Third, a bidirectional or mutual relationship confirms what is known as the *feedback hypothesis*. In the fourth case, no evidence of any relationship between the two variables is found. This is often referred to as the *neutrality hypothesis*. In the first three cases, national energy and environmental policies must be carefully designed to take the energy-GDP relationship into consideration.

As a result of the growing interest in climate change and of the focus of the mitigation activities on the energy sector, and as a result of the rising cost of energy, energy conservation policies have seen a strong comeback in many countries. As can be seen from the aforementioned relationships, however, at least in one of the cases, such a policy may negatively impact the economy (Sentsho, 2002).

Recent studies assert that natural-resource abundance and particularly minerals have adverse consequences in terms of economic growth. Numerous researchers have supported the view that resource-poor countries often outperform resource-rich countries in economic growth. Sachs and Warner (1995a) found a negative association between natural-resource abundance and economic growth in a large cross-country study, but a substantial number of papers have since considered the natural-resource curse hypothesis from different points of view.

The explicit consideration of various transmission channels of the effects of natural-resource abundance on economic growth has led to more differentiated and ambiguous results (Brunnschweiler, 2008). Some scholars concentrate on different links with human capital, and show that the negative economic-growth effects of natural resources stem from lower education spending and less schooling in resource-rich countries; others find that the negative resource effects can be offset by higher education levels, making natural-resource abundance a boom for countries with high human-capital levels. Some others focus on the effects of natural-resource abundance on rent-seeking behavior and income.

Despite the fact that there several recent studies have shown that institutions matter in development (e.g., Acemoglu et al., 2001), the role of institutional quality has received limited attention in the works on economic growth with resource abundance. A notable recent contribution offers a rare theoretical explanation of the resource curse based on a country’s political institutions (Robinson et al., 2006).

This essay explores the theoretical and the empirical issues related to energy consumption, copper production, and economic growth. It consists of six chapters. Chapter 1 includes the introduction, explains the need for the study, and presents the objectives of the study. The chapter also discusses the background theory of the economics of energy consumption and economic growth along with the role of copper and the issues related to the commodity price in the international market and economic growth. Chapter 2 presents the historical background of DRC, including an overview of its political and economic situation and its mining and energy sectors, highlighting the country's particularities to provide an extensive view of the country's situation. In Chapter 3, the existing literature on energy consumption and economic growth on one hand and on primary-resources export and economic growth on the other hand is reviewed. Chapter 4 delineates the method and analytical framework that were used for the study, including the econometric methods that were employed: long-run equilibrium, unit root test methods, cointegration test methods, vector autoregressive (VAR) model, and Granger causality test. Chapter 5 presents the data that were used for the study and presents the estimation results and interpretations. Finally, the conclusions and policy implications are presented in Chapter 6.

1.1 Objectives of the study

The central objective of this study was to investigate the long-run relationship among economic growth (as measured by gross domestic product or GDP), energy consumption, copper production, and copper price in the international market for the Democratic Republic of the Congo (DRC) during the period 1970-2010.

Study motivation

This study was motivated by a number of factors. First, there is a dearth of studies investigating the interdependence of GDP and energy consumption, the interdependence of GDP and copper production, and the interdependence of copper production and copper price for DRC. In fact, almost no empirical studies have been conducted on countries like DRC. Second, this study enriches the existing literature on the copper export by exploring the interdependence between GDP and the production of copper, which is exclusively exported, and its price. Third, this study covers a period that saw some of the most important economic, political, and social events and transformations that occurred in the country. Fourth, it is important to note that DRC has been endowed with huge potential in energy and mineral resources. As one of the big producers and exporters of copper in the world, DRC is faced with the challenge of economic growth. From 2004 to 2011, the average annual growth rate of DRC was 6.6%. Presently, the government of DRC is taking a conscious step towards moving the economy from its deplorable condition to a better state. Apart from the government's various economic, financial, and social reform initiatives, great attention has been focused on the energy and mining sectors of the economy. Thus, it is interesting to investigate the interdependence between economic growth and the aforementioned variables to understand the effect of these structural reforms on the economic development of DRC at some point.

The specific objectives of this dissertation were the following:

(1) to come up with a dynamic time series econometric model for DRC that captures the relationships among energy consumption, economic growth, copper production, and copper price; and

(2) to test for the causal relationship between each pair of variables: economic growth and energy consumption, economic growth and copper production, copper production and energy consumption, and copper production and copper price in the international market.

1.2 Growth models

Economic growth and its sources are major research areas in economics. When analyzing economic growth, the Solow model of economic growth is of great use as a general approach. The Solow model is a dynamic model that is commonly used in light of today's more advanced macroeconomic theory. Romer (2001) argued that an understanding of the Solow model is essential if the theories of growth are to be fully understood.

Robert Solow (1956) developed a model that attempted to describe the long-run evolution of the economy, known as the *neoclassical growth model* (equations I-1 to I-3).

$$y_t = A * f(N_t, K_t), \quad \text{(I-1)}$$

$$K_{t+1} = \mathrm{I}_t + (1 - \delta)K_t, \quad \text{(I-2)}$$

$$N_{t+1} = (1 + n)N_t, \quad \text{(I-3)}$$

where y_t is the production (output or income), A the technological level, N_t

the population (labor), K_t the capital stock, and I_t the investment. Equation (I-2) refers to capital accumulation and equation (I-3), population growth. Constant returns to scale in capital and effective labor are assumed, and there are diminishing returns to each input (F''<0). Solow's (1956) growth model of per-capita output depends on technological progress, and in such model, the economy reaches a stationary state in which there is no additional investment.

It is evident that an increase in technological knowledge will raise the rate of return of capital, thereby compensating for the diminishing returns of capital that will otherwise impede growth. The following two conditions were later added to the basic model:

$$S_t = s * y_t \tag{I-4}$$

$$I_t = S_t, \tag{I-5}$$

where S_t denotes savings. Equation (I-4) refers to the decision of savings from production (or income), and equation (I-5) represents the quality of savings and investment.

In Solow's (1956) model, an underdeveloped economy can accomplish fast growth while accumulating capital stock. If the savings rate remains constant, however, all economies will finally reach zero-growth equilibrium. No country can permanently grow only by accumulating capital (Stern & Cleveland, 2004).

Solow's (1956) model, however, could not explain the improvements in technology and also failed to explain why some countries consistently appear to grow faster than others do. The assumption is that this happens exogenously, and therefore, these models are said to show exogenous technological change. The more recent models, on the other hand, have attempted to endogenize technological change, explaining technological progress within the growth model.

Endogenous growth models endogenize technological progress, which is caused by the accumulation of knowledge and human capital. Early endogenous growth models such as Arrow's (1962) and Hicks's (1963) made technology respond to change in one of the variables in the model. Mankiw et al. (1992) showed that their augmented Solow model was a good fit for the cross-country data. They expanded the Solow model to include human capital with the following model:

$$y_t = K^{\alpha} H^{\beta} (AL)^{1-\alpha-\beta} \quad \text{(I-6)}$$

where H is the stock of human capital and L denotes labor. Islam (1995) used a dynamic panel data model to estimate the growth model, which is based on Mankiw et al.'s argument (1992). The Schumpeterian growth models explicitly model the incentive structure that investments for innovation (i.e., research and development activities) bring monopoly profits to firms (Aghion & Howitt, 1998).

The fact that natural resources are finite and exhaustive makes the notion of economic growth questionable. The notion of sustainability in the context of natural resources in growth models has been discussed by several researchers. Solow (1974b) introduced a rate of flow of a natural resource (R) into the production function (equation I-7).

$$Q = F(K, L, R) \tag{I-7}$$

Through the Cobb-Douglas formulation, equation (I-7) can be expressed as follows:

$$Q = e^{mgt} L^{g} R^{h} K^{1-g-h} \tag{I-8}$$

where mg is the rate of Hicks-neutral technical progress and m is the rate of labor-augmenting progress. With this formulation, Solow (1974b) discussed exhaustible resources in the same framework that had been applied to general growth models, and showed that sustainability is achievable with three conditions: a finite and non-renewable natural resource with no extraction costs exists and non-depreciating capital is available, the elasticity of substitution between the two inputs is unity, and certain other technical conditions are satisfied.

Stieglitz (1974) argued that the same model economy under competitive circumstances results in resource exhaustion, which means that consumption and social welfare eventually fall to zero. Hardwick (1977) showed that a constant level of consumption can be achieved by reinvesting the current exhaustible-resource returns in reproducible capital.

1.3 Discourse on energy consumption and economic growth relationship

1.3.1 Role of energy

Energy is a key factor in the determination of economic growth in modern economies. Individuals and organizations need different energy sources to ensure the sustainability of their businesses. It has also been proven that the energy sector, which includes electricity, oil, gas, and renewable energy, plays a significant role in the economic development of any country. This developmental effect can be seen not only in the improved labor and capital productivity due to a reliable energy sector but also in the fact that energy consumption is a sign of the good health of the economy in developing countries. Using the World Development Indicator or WDI (World Bank, 2008), these authors noticed that the electricity consumption in the developed OECD countries in 2007 was way above the overall electricity consumption (more than four times) while the Sub-Saharan African countries accounted for only 20% and the developing countries only 4% of the global energy consumption (Kouakou, 2011).

1.3.2 Energy consumption and economic growth relationship

A number of studies have attempted to figure out the relationship between energy consumption and economic growth from various perspectives besides the growth theories. The econometrics methods analyzing the long-run relationship that can exist between energy consumption and economic growth involve the cointegration and causality concepts.

Investigating indicators such as energy intensity and elasticity of energy also gives useful information for analyzing such relationship. Stern and Cleveland (2004) thoroughly reviewed the relationship between energy and economic growth. They discussed the relationship under four categories: substitution and complementarity of energy and capital, innovation and energy efficiency, energy quality and shifts in the composition of the energy input, and shifts in the composition of the output.

The following five factors can affect the relationship between energy consumption and economic growth (Stern & Cleveland, 2004): substitution of energy with other inputs, technological change, shifts in the composition of the energy input, shifts in the composition of the output, and shifts in the mix of the other inputs.

1.4 Discourse on primary export and economic growth linkage

1.4.1 Role of copper

Copper is a relatively inexpensive and extremely plentiful metal with numerous useful properties. It effectively resists corrosion and is a very effective conductor of both electricity and heat. This quite naturally makes copper a prominently relied upon and utilized "centerpiece" of any emerging or expanding industrial economy. From electrical wiring to plumbing and from radiators to air conditioners, almost all commodities require the use of copper. This is because copper is such a greatly relied upon, highly valued, and widely utilized metallic element within every aspect of a society undergoing a serious growth phase and process of advancing towards a more state-of-the-art existence. This means that whether talking about massive construction projects, infrastructure renewal, telecommunications modifications, or medical, technological, and/or energy option exploration and research, if it is happening, then copper is in use.

Over the past century, the "industrial" demand alone for refined copper increased from 500,000 metric tons to over 19 million metric tons. As the increasingly smaller world continues to experience population growth along with progressive expansion, the demand for copper is expected to increase exponentially.

The dramatic rise in the need for copper will naturally increase the demand for new mines and processing plants as the current facilities are upgraded and expanded. As “less developed” regions begin to expand their infrastructures, copper will naturally serve as the most reliable building block with which to build a new civilization and improve upon average living standards. A perfect illustration of this is what has been observed in line with the recent Chinese construction boom.

1.4.2 Commodity prices and economic growth

African economies export primary commodities, and most export little else. Policymakers as well as economists and historians of African economic development have seen these exports as both a source of hope and a curse (Deaton, 1999). Researches have been done on commodity prices touching on African economic development; fuller accounts are given in Gersovitz and Paxson (1990), Deaton and Miller (1995), and Collier and Gunning (1999).

Davis and Tilton (2005) argued that the market for primary products, including mineral commodities, is known for its instability. In the case of mineral commodities, this volatility arises because the demand fluctuates greatly over the business cycle. There are two other conditions that contribute to the short-run fluctuations in the mineral commodity prices. First, the elasticity or responsiveness of the demand to changes in price is small in the short run. Second, the elasticity or responsiveness of the supply to changes in price is also small in the short run once the output approaches the existing capacity. When the economy is booming, the end-use sectors that consume most of the mineral commodities — construction, capital equipment, transportation, and consumer durables — expand even faster than the economy does in recession. As such, when the economy is in recession, these sectors are usually even more depressed.

As instability in the metal markets arises primarily because of the shifts in demand, when the output is up, so are the prices. This means that profits, and the taxes governments collect on them, are particularly volatile. If the price volatility is supply-driven, decreasing prices will be met with increasing quantities, stabilizing revenues. If it is demand-driven, the two will reinforce each other. The latter is accepted (Yukawa, 1988).

Therefore, market instability makes it difficult for developing countries to count on revenue from the mineral sector, and hampers the effective planning needed for economic development. It also means that government revenues and foreign exchange earnings are curtailed exactly when an expansionary monetary policy is needed to help the domestic economy weather a recession in a vital economic sector.

There are various accounts and interpretations of African countries' political and economic responses to commodity price fluctuations. In particular, it is argued that the difficulties of handling price fluctuations are so severe, and policymaking in African countries so dysfunctional, that price booms and price slumps are equally to be feared. Empirical evidence has shown a close positive relationship between commodity price movements and growth. While this evidence is hardly exculpatory for all African governments, some of whom have undoubtedly been guilty of egregiously inappropriate policies, it is consistent with the commonsensical economic view that it is better to receive than to give. Additional income from commodity price booms helps the economies of African producer countries, just as they are hurt by the loss of income during slumps.

Empirical evidence has shown a close positive relationship between commodity price movements and growth. Even if there has been progress, the understanding of commodity prices and the ability to forecast them remain seriously inadequate. Without such understanding, it is difficult to construct good policy rules.

As most of the developing economies depend on primary commodity exports but the degree of processing of primary commodity exports is generally low, these exports have in common a relatively small share of labor in their value, and it is known that their prices behave differently from the prices of manufactured exports. Developing countries' exports of these commodities represent too small a share of the world exports to permit individual countries to have much effect on world prices. This is what explains why price fixing is beyond primary-commodity exporter countries.

Although several commodities are important for a number of countries, some commodities are important only to one or two countries, such as copper in DRC and Zambia, diamond in Botswana, phosphate in Togo, and iron ore in Mauritania. The diversity is important because the prices of different commodities do not move parallel to one another. The production conditions are also heterogeneous across countries, as are the social and economic characteristics of the producers. Minerals (except sometimes diamonds) are usually produced in "enclaves," are owned or mined by foreign interests or by the state, and are readily subjected to high taxes or royalties. As a result, fluctuations in mineral revenues typically accrue directly to the state.

Why do commodity prices move as they do?

Deaton (1999) argued that the sensible development and macroeconomic policy rules for commodity-exporting countries must be grounded in an understanding of the behavior of commodity prices. The urgency and attractiveness of export diversification depend greatly on whether real prices can be expected to trend up or down in the future. The intertemporal smoothing of how much of revenues should be spent and how much should be saved requires that governments and private individuals understand what drives price swings and the length of time they are likely to be prolonged.

The basic story for primary-commodity prices, however, remains unchanged: real prices cannot rise as long as there is an unlimited supply of labor at the subsistence wage, and will fall in response to local technical progress.

Supply shocks are typically thought to be large; wars, pestilence, disease, weather, and political upheaval are all capable of causing large, albeit usually temporary, shortfalls in production. If the demand functions for foods and minerals are price-inelastic, the price variance can be several times the variance of the fundamental supply shocks. The role of supply shocks, however, is not straightforward.

Storage by speculators can be expected to move commodities from periods of low prices to periods of high prices, thus inducing autocorrelation, and simulations of prices where independent supply shocks are modified by speculative storage do indeed reproduce some of the characteristics of actual prices, including long periods of "doldrums" punctuated by sharp upward spikes (Deaton & Laroque, 1992).

Fluctuations on the demand side are clearly part of the explanation both for the correlation of individual prices with their own past history and for the correlation across different prices at a moment of time. So are fluctuations in world interest rates, which affect demand through the cost of storage.

In view of these difficulties, empirical analysts have had great difficulty in building satisfactory models of commodity prices, and consequently, exporting developing countries have been provided with advice that was often not useful and was occasionally downright misleading.

Therefore, policy prescriptions from well-fitting but inappropriate models are potentially catastrophic: income from a commodity boom, instead of being seen as a long-lived but ultimately temporary windfall, is misdiagnosed as permanent (the random-walk case) or as the first installment of an even larger windfall in the offing (when price changes are positively autocorrelated) so that the consumption should rise by even more than the current windfall income does.

Variable commodity prices are beneficial for producers because they provide the latter with the opportunity to supply more when the prices are high, and to withhold supply when the prices are low, so that the variability around an unchanged mean increases the expected revenue.

Consumption, however, should not follow the variability of income, and it can be difficult for policymakers to handle large fluctuations in private and public revenues without an understanding of how long each boom or bust is likely to last. Smoothing an uncorrelated or negatively correlated income stream is relatively straightforward because it calls for minimal action. Handling positive autocorrelation is much harder, especially if, as is the case for most African countries for most of the time, there is limited or no access to international capital markets.

The accumulation of large reserves over many years may not be politically feasible for a regime where spending opportunities are rare, and if the ensuing slump lasts longer than the boom, such accumulations may in any case have a minimal effect on consumption after the boom. When the autocorrelation is large, the accumulation of buffer stocks is both expensive and ineffective (Deaton, 1999). Nor is international price variability the only source of income fluctuations. To the extent that prices are driven by quantities, income may be less variable than price.

In short, it can be concluded that the revenue from commodity exports provides a potential source of investment funds. Even temporary price booms provide windfalls that, if wisely invested, can enhance future growth and development.

In the case of DRC, where the state has played a large part in investment projects, a more endemic problem has been the low quality of investment and a general absence of project evaluation for what has been often political and pork-barrel spending. A strategy of industrialization aimed at having domestic production displace imports, financed by commodity exports, has not been a successful strategy for growth partly because of the absence of complementary factors, particularly education. As such, DRC’s comparative advantage has remained in the production of primary commodities.

Chapter 2. Historical background of the DR Congo

2.1 Political situation the DR Congo

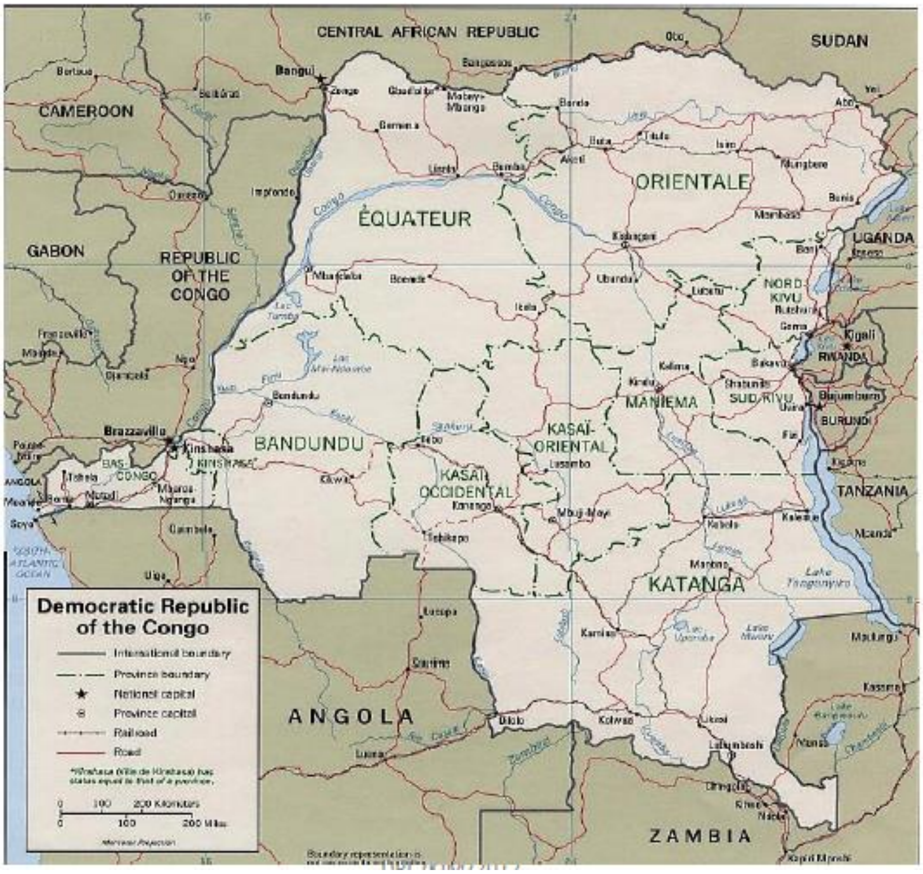

Figure 2.0: The administrative map of the Democratic Republic of Congo

The Democratic Republic of Congo (DRC) located in the central African region, with an area of 2,345,410 square kilometers is currently among poor countries in the Africa continent despite the fact that it is richly endowed with natural resources and vast mineral deposit proven worldwide. This is partly due to many factors that DRC have been facing since its independence in 30th June 1960 from the Belgian colony. DRC is bordering with nine countries namely Angola (2,511 km of which 225 km is the boundary of Angola's Cabinda Province), Burundi (233 km),Central African Republic (1,577 km), Republic of Congo(2,410 km), Rwanda (217km), South Sudan (628 km), Tanzania (459 km), Uganda (765 km), and Zambia (1,930 km) (Figure 2.0).

The DRC had a tumultuous past political history which can be summarize as follow as argued by Nzongola-Ntalaja (2002):

From 1885 to 1908: it was a personal property of King Leopold of Belgium. Since those days it has gone to serve the interests of the country's rulers and those of their political and business partners in the international community; The King transferred the ownership of the Congo to his country, Belgium due to political and social pressures in 1909. On 30th June, 1960, DRC gained its independence from the kingdom, but the country experienced a political instability from then until 1965 when the President Joseph Mobutu took power by a military putsch and installed the dictatorship from that period until 1997. Since 1996, DRC has been embroiled in a war that once drew seven African countries (Rwanda, Burundi, Uganda, Namibia, Angola, Chad and Zimbabwe) until the Sun City Peace Agreement in 2001. But in the meantime the president Mzee Laurent Kabila who toppled Mobutu from power was assassinated in 2000. In short the political transition period in the DRC lasted 16 years and it started in 1990 to end up with the first free and democratic election held in 2006.

2.2 DRC's economic overview

The Democratic Republic of the Congo (DRC)- a developing country in the central of Africa with a population of 73 million people is endowed with vast natural resources including a vast hydroelectric potential that remains largely untapped.

Despite its economic potential, economic activity showed a drastic decline during the period 1960-2000, as shown in figure 2.1. The dramatic decline in output and income has been the result of inappropriate economic and financial policies, pervasive corruption, and, especially in the past 1990's, political turmoil, civil strife, and full-fledged war since 1998.

However, since early 2001, the government of DRC took a conscious step toward moving the economy from it deplorable condition to a better state by stabilizing the macroeconomic parameters, liberalization policy of the overall market (particularly mining and energy sector, etc..) and opening the economy up to the rest of the world. In 2002, for the first time in 13 years, real GDP growth was estimated to be positive, about +3.5 % (Table 2.1).

Figure 2.1: DRC-Real GDP per capita (Index 1960=100)

Source: Central Bank of Congo and IMF staff estimates (2003).

Table 2.1: GDP growth rate (%) from 1990 to 2002

Year	GDP growth rate (%)
1990	-6.6
1991	-8.4
1992	-10.5
1993	-13.5
1994	-3.9
1995	+0.7
1996	-1.1
1997	-5.4
1998	-1.7
1999	-4.3
2000	-6.9
2001	-2.1
2002	+3.5

Source: Central Bank of Congo (2011)

Sound macroeconomic policies and the ongoing far-reaching structural reforms have started to have a positive effect on growth through improved resource allocation. From 2002 up to 2011, GDP per capita is in constant growing with an average annual rate of 6.6%. (Table 2.2) and it is excepted that this trend will continue in the years to come as the number of projects with private partners is in constant increase.

Table 2.2: GDP growth rate (%) from 2002 to 2012

Year	GDP Growth Rate (%)	GDP Growth Rate/Cap (%)
2002	+3.5	0.7
2003	+5.8	3.0
2004	+6.6	3.8
2005	+7.8	4.7
2006	+5.6	2.5
2007	+6.3	3.2
2008	+6.3	3.1
2009	+2.8	-0.2
2010	+7.1	4.1
2011	+6.9	3.8
2012e	+7.4	

Source: Central Bank of Congo (2011)

2.2.1 DRC’s economic performance from 1960-2000

Focusing on the key constraints and policies that have hampered economic growth, this section analyzes both overall and sectoral growth performance. The factors constraining the DRC’s economic performance have included ineffective governance and administrative bottlenecks, ill-conceived economic policies, transportation difficulties, lack of basic infrastructure, and insufficient confidence among potential local and foreign investors (Akitoby and Cinyabuguma , 2004).

The DRC’s overall economic performance has been extremely disappointing, notwithstanding the country’s rich endowments of natural and human resources. The real GDP in 2000 is below its 1960 level (Figure 2.2).

Figure 2.2: DR Congo-Real GDP (Index, 1960 = 100)
Source: Central Bank of Congo and IMF staff estimates.(2003)

Following Maton et al (1998), the evolution in real GDP since 1960 can be usefully divided into five sub-periods: (a) 1960–65: political chaos and economic disruption; (b) 1966–74: stability and growth; (c) 1975–82: economic recession and debt crisis; (d) 1983–89: adjustment under the IMF and stop-and-go policies; and (e) 1990–2000: hyperinflation and collapse of the economic and political system. Explanations are here under:

1960–65: Political chaos and economic disruption - This period witnessed a decline in output because of disruption in the transport network and the departure of many foreign entrepreneurs following political turmoil, civil strife, and the failed secession of the Katanga Province. Real GDP declined by about 4 percent between 1960 and 1965.

1966–74: Stability and growth - This period was characterized by increased involvement of the state in the productive sectors of the economy. Thanks to La Politique des Grands Travaux,3 public investment quadrupled.

In 1971, the first Mobutu plan (Plan Décennal 1971–80) was launched, which aimed to raise real GDP growth to about 7 percent per year. Against this backdrop, in 1973–74 the government took steps toward the nationalization of all small, medium-sized, and large foreign enterprises. Increasing state control of the economy was accompanied by an impressive economic expansion, with real GDP growing at an average annual rate of 5.1 percent during 1966–74.

However, following the adverse terms of trade shocks caused by both a reversal in copper prices and the oil crisis of 1973, the centralized economy, unable to adjust, soon revealed its severe limitations.

1975–82: Economic recession and debt crisis - The ill-advised economic policies and public investments of the early 1970s precipitated a debt crisis with a damaging impact on economic activity. In 1975, the country stopped servicing its debt and requested an IMF-supported program for the first time to help extricate the DRC from its economic crisis. Because of the overall downturn, the public investment program was grounded, capital invested in “white elephants” was lost, and the maintenance of infrastructure and productive capital was neglected or postponed indefinitely. As a result, economic activity experienced a severe decline, compounded by the invasions of the Katanga Province (the heart of mining activities) in 1977 and 1978. Altogether, real GDP fell by 12 percent.

1983–89: Adjustment supported by the IMF and stop-and-go policies - To improve the economic and financial situation, and eliminate the significant distortions that had grown in the preceding period, the government started to implement in September 1983 a strong stabilization and liberalization program. This strategy had a positive impact as real GDP, which had declined by 2.2 percent in 1982, recovered with an average annual growth rate of 2.6 percent during the period, 1984–86.

In 1987, with the support of the IMF and the World Bank, the government launched a structural adjustment program aimed at establishing the basis for long-term economic growth and a sustainable external financial position. The program also benefited from improved terms of trade, mostly reflecting a strong upturn in copper prices beginning in early 1987.

However, with the more favorable external environment, the government all but ceased its adjustment efforts. As a result, the country's financial performance deteriorated markedly. Annual real GDP growth decelerated to 0.5 percent on average during the period 1987–89.

1990–2000: Hyperinflation and collapse of the economic and political system - In the midst of failed attempts at political liberalization, control over economic policies was lost, and the country fell into the grip of an unprecedented circle of hyperinflation, currency depreciation, increasing dollarization and financial disintermediation, declining savings, deteriorating economic infrastructure, and broad-based output decline. The alarming economic and social situation was compounded by the full-fledged war that broke out on August 2, 1998.

In this context, a large part of the country's capital stock was destroyed, and investment was discouraged. As a result, real GDP contracted cumulatively by some 43 percent during the decade, and per capita real GDP plummeted from US$224 in 1990 to US$85 (23 cents a day) in 2000. Over the same period, consumer prices rose at an annual average rate of 684 percent. Government revenue fell by 80 percent, and external debt rose to about 300 percent of GDP (or almost US$13 billion).

2.2.2 Recent Economic Performance

The DRC requires rapid economic growth in order to raise its economic and development status. GDP growth over the period 2002-2010 is estimated by the IMF to have averaged 6.6% per year thanks in part to generally rising mineral demand and prices, which are especially important to this commodity-dependent nation.

Following the structural reforms undertaking since 2001, GDP per capita has been growing positively since then up to date (Figure 2.3). Even so, the GDP per capita estimated using purchasing power parity of the country remains low compared to others Sub Saharan African countries.

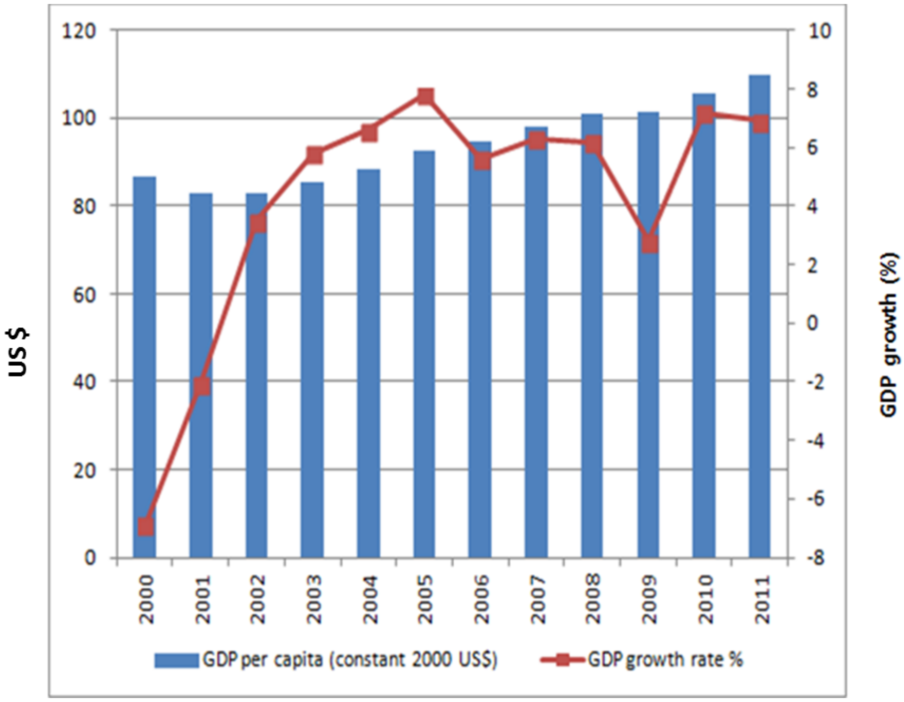

Figure 2.3: DRC's GDP growth from 2000 to 2011
(World Bank, 2011)

In addition, benefits that accrued from the improving if not fully resolved security situation in the DRC included an influx of capital investment and credit expansion, with net domestic credit having expanded 35% on average over the years 2003-2008 (IMF, 2010).

Foreign investment has been boosted by large Chinese/DRC investment agreements, including the joint agreements in 2008 with the China Railway Group, Sinohydro Corporation and the Metallurgical Group Corporation reportedly totalling US$ 9 billion that exchange infrastructure investment for copper and cobalt mining concessions.

By sector, the economic expansion has been driven not only by the mining and wholesale and retail trade sectors, but also by solid growth in transport, communications, construction and public works spending (Figure 2.4).

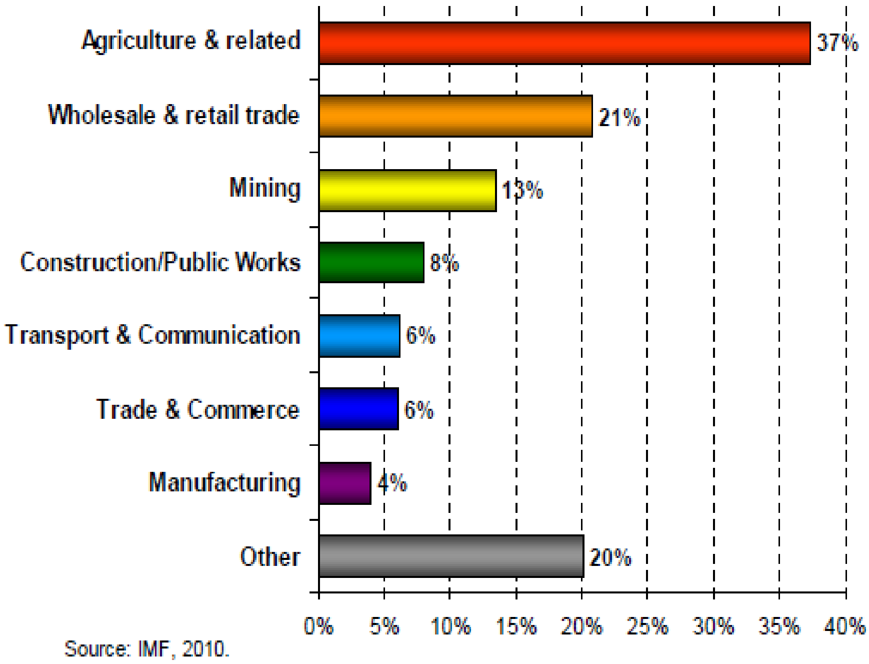

Figure 2.4: DRC GDP by Sector, 2010 (% of GDP)
Source: IMF, 2010

2.3 Mineral sector in the DR Congo

Since independence, mining activity has been the main engine of the DRC economy. But the revenues and other benefit streams generated by the sector have not been used in a wise and/or sustainable fashion; largely due to key problems with the sector governance. Until now mining activity remained the country's principal industrial activity.

2.3.1 Mineral deposits and production

The Democratic Republic of the Congo (DRC) holds some of the world's largest deposits of copper and cobalt, as well as significant reserves of gold, diamonds, tin, iron, zinc, iron, columbite tantalite, tin, uranium, germanium, etc. (Table 2.3).

Table 2.3: Reserves of different mineral commodities

No	Mineral	Reserves tons	Status
01	Cobalt	5,000,000	exploitation
02	Copper	75,000,000	exploitation
03	Diamond	260,000,000 carats	exploitation
04	Gold	3,096	exploitation
05	Iron	20,000,000,000	Non exploit
06	Lithium	31,000,000	exploitation
07	Niobium (Coltan)	30,000,000	Non exploit
08	Nickel-Chomium	22,500,000	exploitation
09	Manganese	7,000,000	exploitation
10	Tinstone	450,000	exploitation
11	Zinc	7,000,000	exploitation
12	Uranium	NA	stopped

Source: Ministry of Mines (DRC)

The most active regions in mining activities in the DRC are Katanga (copper and cobalt mainly), East-Kasaï (diamond), Ituri in the current Oriental Province (gold) and the Kivu’s (gold, tin, colombo-tantalite). However, other provinces also have mineral occurrences and/or potential, much of which has not yet been explored. Known mineral deposits in the country are displayed in Table 2.4 and their geographic locations in Figures 2.5-1-2-3 respectively.

Table 2.4: DRC's Mineral endowments by province

Province	Minerals
Bandundu	Diamond, gold
Bas Congo	Bauxite, gold, oil shales, limestone, phosphate, vanadium, diamond, petroleum
Equateur	Iron, copper and associates, gold, diamond
Orientale	Gold, diamond, iron
Kasai Oriental	Diamond, iron, silver, nickel
Kasai Occidental	Diamond, gold, manganese, chrome, nickel
Katanga	Copper and associates, cobalt, manganese, limestone, uranium, coal, uranium, zinc, cassiterite, iron, coltan
North Kivu	Gold, niobium, tantalite, cassiterite, beryl, tungsten, monazite
South Kivu	Gold, niobium, tantalite, cassiterite, sapphire
Maniema	Tin, diamond, cassiterite, coltan

Source: Ministry of Mines (DRC)

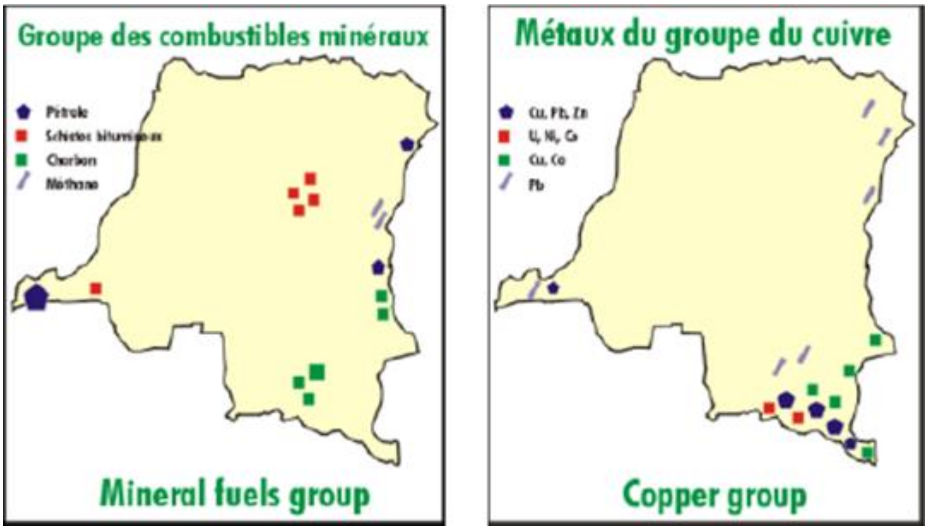

Figure 2.5-1: DRC's metallogenic map of mineral fuels and copper
Source: Ministry of Mines (DRC)

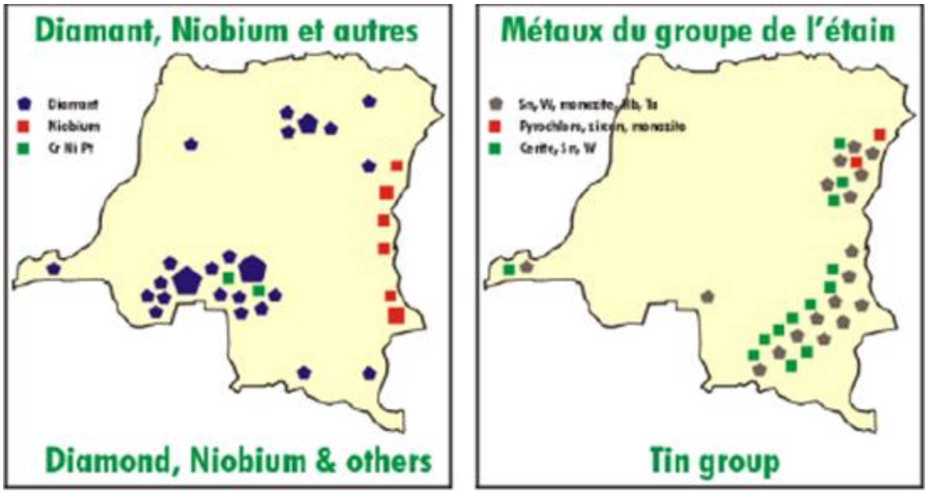

Figure 2.5-2: DRC's metallogenic map of diamond-niobium & tin
Source: Ministry of Mines (DRC)

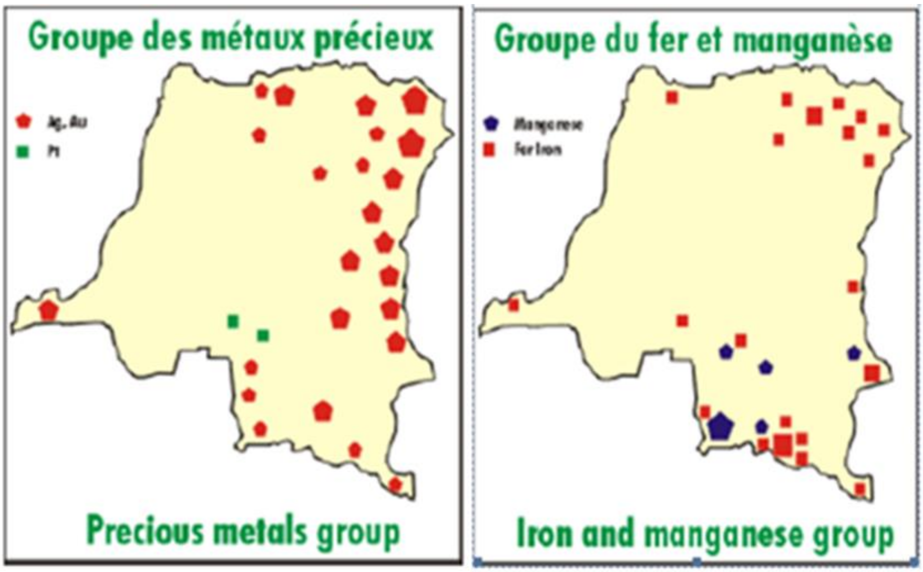

Figure 2.5-3: DRC's metallogenic map of precious metals & iron group
Source: Ministry of Mines (DRC)

Nationalization and privatization in the sector

In 1966, the DRC (then called Zaire) government started the process of nationalization of the private mining enterprises and creating the state owned enterprises. Gécamines, the largest mining state owned enterprise in DRC exploiting copper and its associated minerals was created in 1967 following the nationalization of UMHK, a Belgian private company. The Office d'Or de Kilo-Moto (OKIMO) a 100% state owned company exploiting gold deposits was created in 1966. The State also acquired a majority in the diamond company (MIBA) where 80% owned by the state and 20% by the Belgian side. Despite the rich mineral provinces these state companies became non-profitable. Other service activities such as transport, energy and telecommunications also became problematic and ceased to render good services to the mining activities further aggravating the situation.

DRC's mining sector has been dominated for years by these large enterprises owned by the government. The enterprises have operated not as commercial enterprises but virtually as governments within a government – running schools, farms to produce food for employees, hospitals, social centers, transport, energy, and water infrastructure for the province. This system functioned well enough during the colonial period, but began a long descent in the mid-1970s. The Central Government deprived them of cash surpluses which should have been used for re-investment.

During the 1970s, when copper prices were high, GÉCAMINES was unable to use the surpluses to renovate existing facilities or to invest in new technologies, as its competitors were doing. Directors and senior managers of the companies were appointed by the Central Government on the basis of politics rather than their commercial and technical abilities. The companies' workforces were out of proportion to production levels, resulting in low productivity.

The disruptions to security and supply chain management difficult to access supplies or markets, forcing cutbacks in production. The result of these factors was that state-owned mining enterprises in DRC have slowly descended into insolvency, with severe repercussions for employees and the communities which depend on the enterprises for infrastructure services. (Andre-Dumont, 2011).

Today, a major challenge for the Government is to determine what should be done with the enterprises, taking into account the special circumstances of existing workforce and social commitments, as well as the generic difficulties attendant to radical restructuring of dominant state enterprises in post-conflict states.

Mining production level of different commodities

In the 1980s the extractive sector accounted for about 75 per cent of total export earnings, 25 per cent of the country's GDP and 25 per cent of fiscal revenue. However, major civil conflicts and political instability disrupted the country's resource development. (World Bank, 2006). DRC is exactly classified as a mineral economy by the UN definition those countries generating at least 10% of gross domestic product from mining and at least 40% of their foreign exchange earnings from mineral exports (United Nations, 1998, p.2)

During the same period, the mining sector has been facing a number of problems that have constrained its development. These include: a legal and regulatory framework not conducive to the development of the private sector; serious transportation problems and chronic lack of investment.

Early 1990s, the national mineral production of all minerals declined substantially and that was the collapse of all the State-Owned Enterprises, with significant repercussions on the whole economy. Figures: 2.6-7-8-9 show the level of production of four (4) commodities: copper, zinc, gold and diamond have shown a very significant decline over the last decade until the passage of the new Mining Code adopted in 2002 and its ancillary Mining Regulation, adopted in 2003.

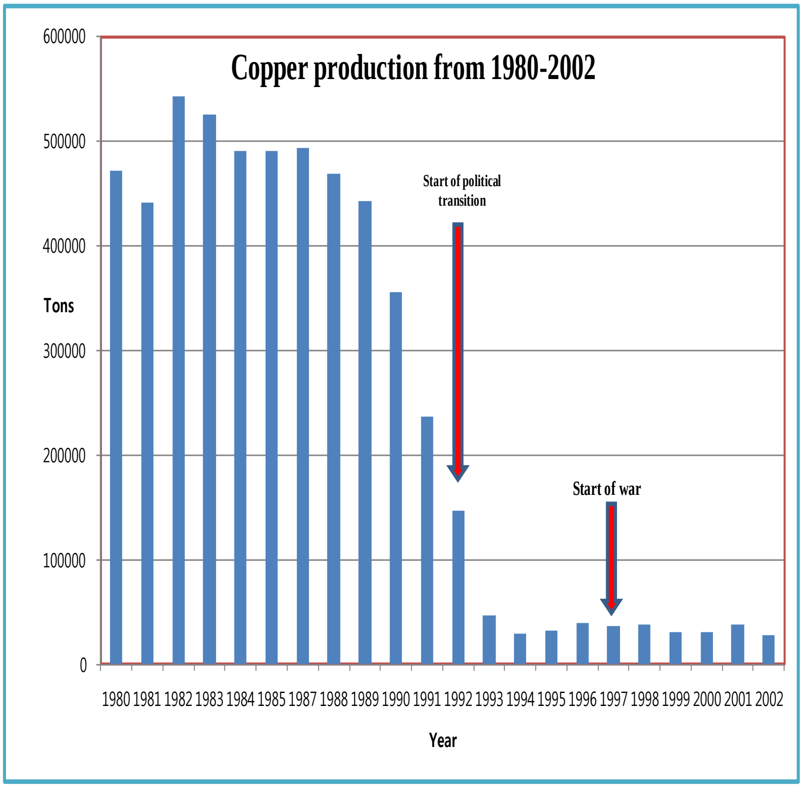

Figure 2.6: DRC's Copper production from 1980-2002
Source: Ministry of Mines/ statistics of production 2002

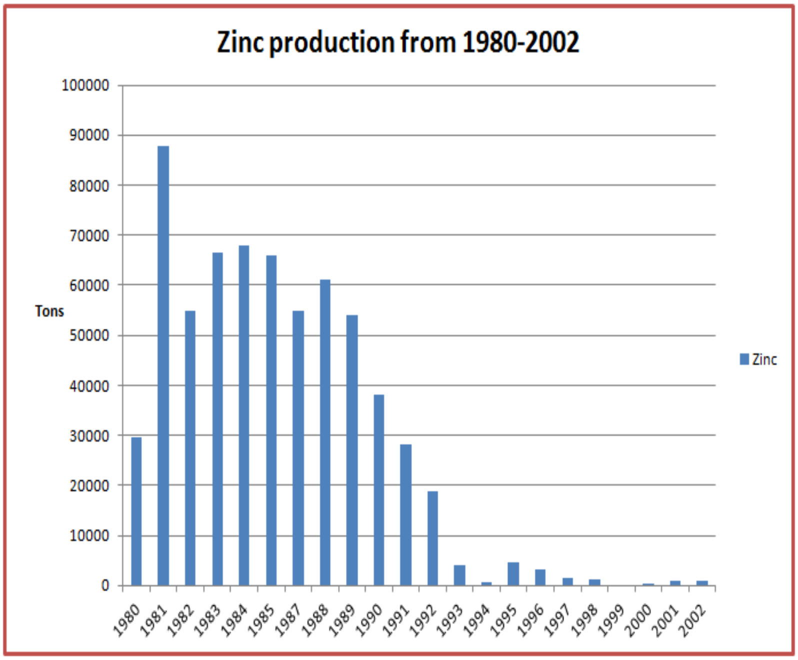

Figure 2.7: DRC's Zinc production from 1980-2002
Source: Ministry of Mines/ statistics of production 2002

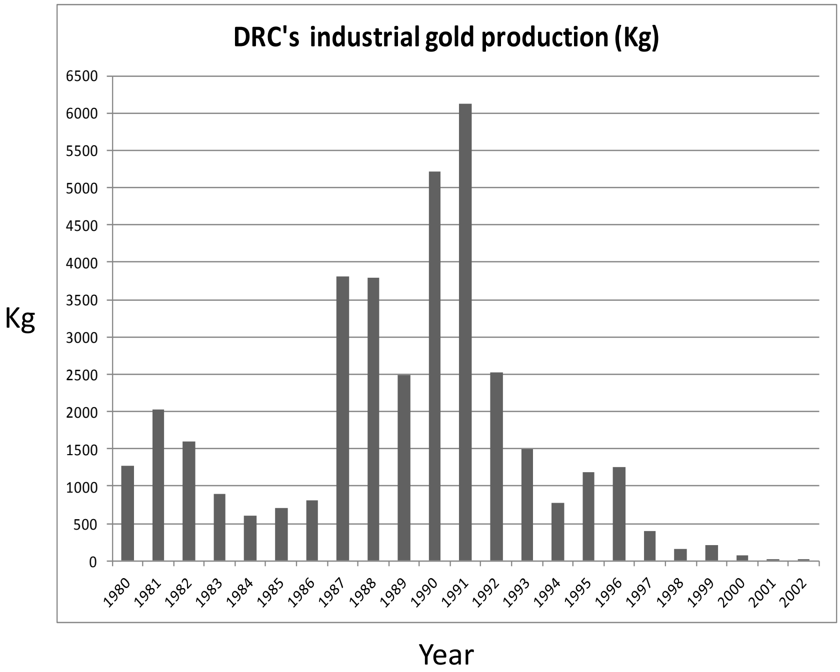

Figure 2.8: DRC's Gold production from 1980-2002
Source: Ministry of Mines/ statistics of production 2002

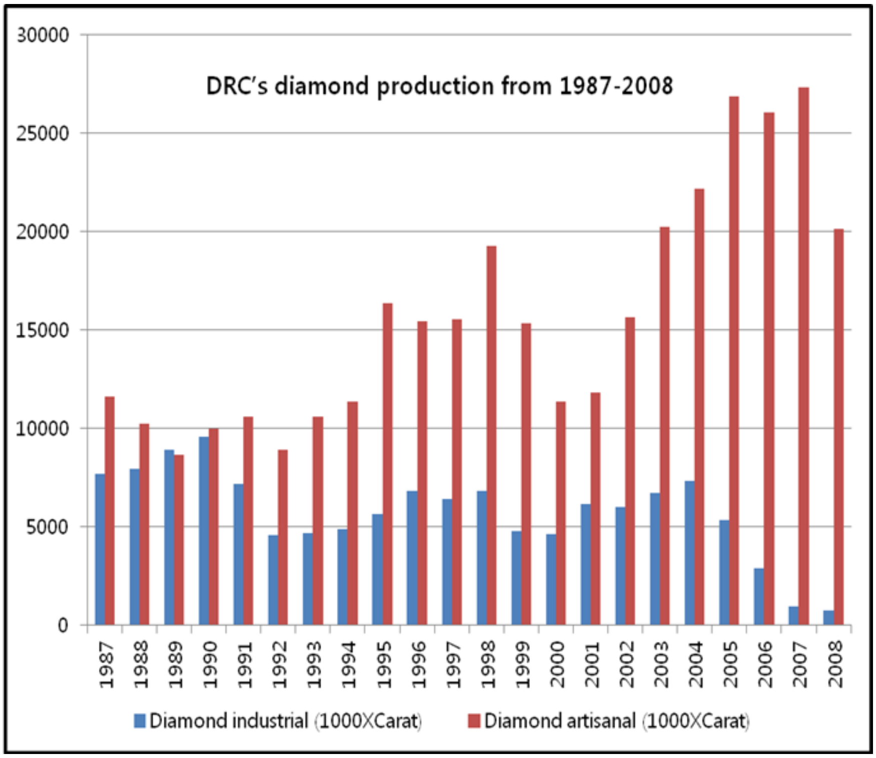

Figure 2.9: DRC's Diamond production from 1987-2008
Source: Ministry of mines/ statistics of production 2010

From the Figure 2.9, one can see that the diamond industrial production has declined drastically since 1990s and is still lagging behind the artisanal sector which has expanded. As DRC's industrial mining sector has declined during the political period of instability, the artisanal and small-scale mining has then expanded more during the war period because the people depend on artisanal mining. There are an estimated 10 million people, 7 percent of DRC's population, who either mine directly or are dependent on artisanal mining for their livelihood. Artisans are present in the production of virtually all commodities: gold in Ituri province, diamonds in the two kasai provinces and cassiterite/coltan in the Kivu's and Maniema provinces. The artisanal sector presents several challenges for the central government that are distinct from those in other segments of the mining sector. This is beyond the scope of our study.

Public private partnership in the mining sector in DRC

Beginning in the mid-1990s, the Government authorized the state-owned companies to enter into partnership agreements with private sector companies for the development of mineral resources. Some of these partnership agreements provide for the mineral rights held by the state-owned enterprise to be transferred to a new entity established under the terms of the agreement. In other instances, the mineral rights are leased to the private sector partner under the terms of the agreement.

The most significant step in the implementation of the public private partnership (PPP) was the passage in 2002 of a new Mining Code the new Mining Code adopted that year and its ancillary Mining Regulation, adopted in 2003 which was elaborated under the supervision of the World Bank. The Mining Code has made also possible for private sector companies to hold mineral rights for exploration and exploitation without a partnership with a state-owned enterprise. This approach holds much promise, and the government is enforcing compliance with applicable regulations and contractual obligations.

Most of the state-owned enterprises have signed agreements of partnership with private companies and/or private investors. But up to date, the PPP is effective and very active in the copper sector than in the diamond, gold and cassiterite/coltan sectors. This can be easily understandable because the mining industry is one of the most complex and competitive industrial sectors in the world. Private mining companies operate in the international marketplace, where many commercial, financial, and political factors influence their decisions about investments in developing countries. The gold and cassiterite/coltan deposits a located in the Eastern part of the DRC where there are some actions from Uganda (LRA) in Ituri province and from Rwanda in the Kivu's provinces.

The private sector companies are very active in exploration and exploitation operations in the copper sector, with or without partnership agreements with the state-owned company (Gecamines), which has been also corporatized. It is estimated that private companies and partnerships are spending a total of US$ 60 million per year on exploration which is essential to discover new ore reserves. The copper sector is expanding since then.

The figure 2.10 shows the level of production of copper which have shown a rising up since the passage in 2002 of a new Mining Code and Regulations and a very significant rising after the first free and democratic election in 2006.

- In addition , there is a number of projects which are currently either under construction or in the advanced planning stages, and will come on stream by 2013,
- Values from 2012 to 2015, in the figure are expected values.

It is clear therefore that the copper sector will be playing an important role in the DRC's economy for the years to come.

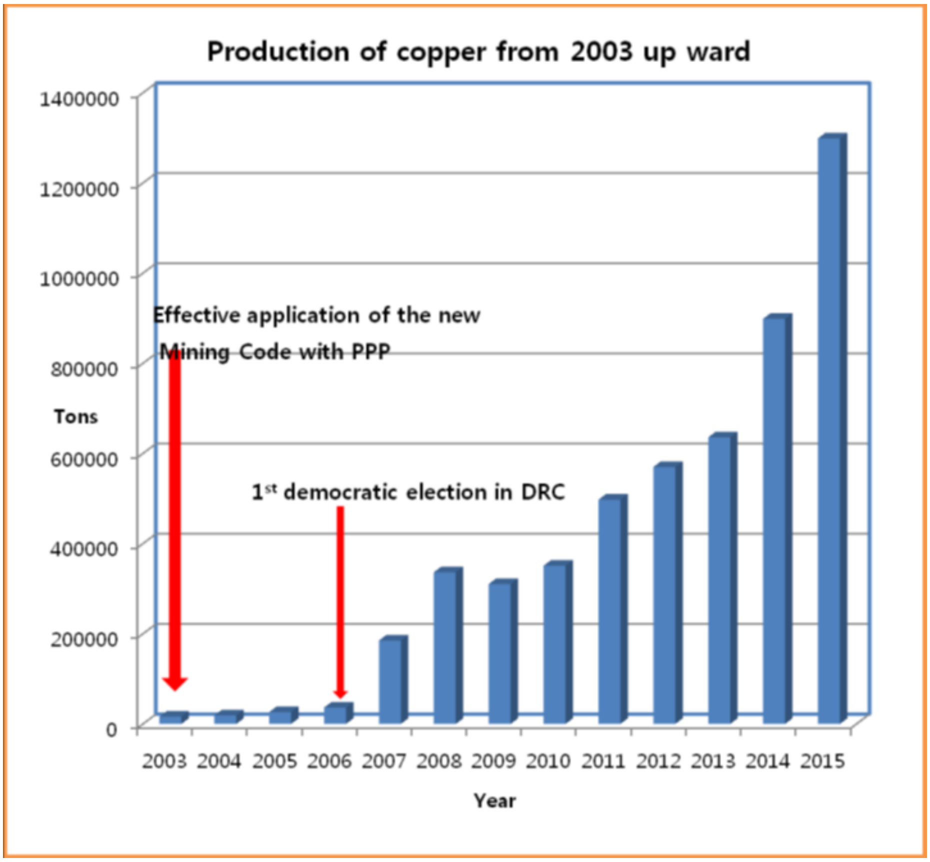

Figure 2.10: DRC's Copper production from 2002 up ward
Source: Ministry of mines/ statistics of production 2011

2.3.2 Structure of the Economy and Copper's Contribution

With estimated per capita GDP (purchasing power basis) of US$ 300 in 2009, the Democratic Republic of the Congo (DRC) ranked 227 out of 228 countries in that category (ahead of only Zimbabwe) and remains one of the least developed nations in the world, despite its wealth of natural resources.

As with many least developed countries, the DRC is heavily reliant upon commodity production, with agriculture, mining and related industries estimated to have accounted for just over 50% of GDP in 2008 (CIA, 2010)1. In contrast, manufacturing, public administration and related services, and electricity and water generation accounted for just 4%, 2% and 1% of GDP respectively in 2010 (Figure 2.4).

Although the share of GDP attributable to the primary sector (mining, agriculture and related industries) as a whole decreased from 57% of DR Congo's GDP in 2003 to 50.7% in 2010, the sector's diminishing importance masks divergent underlying trends. The mining sector, which includes the processing of minerals, accounted for 13.4% of GDP in the DRC in 2010, up from 12.7% in 2007 and 2% in 2003 according to the IMF.

In terms of year-on-year growth, the mining sector in the DRC grew 11.4% in 2010, the second fastest rate of growth behind wholesale and retail trade. The falling share of the primary sector reflects instead the decreasing relative importance of agriculture and related industries, which fell from 45% of GDP in 2003 to 37% in 2010.

Within the mining sector, the key natural resources in the DRC include copper, cobalt, petroleum, diamonds, gold, silver, zinc, manganese, tin, uranium and coal, among others (BCC, 2011). However, copper and cobalt production are the primary revenue generators. From a low of just 30 thousand metric tons (kt) of copper in 1999, copper mine production in the DRC has increased every year since, reaching nearly 498 kt in 2010 and forecast to approach 600 kt in 2012. Based on data released from the IMF,

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[1]Central Intelligence Agency, 2010.

copper export sales accounted for over one-third of the DR Congo's export earnings in 2010 (IMF, 2010).

DR Congo and world copper production

While copper mine production in the DRC accounted for nearly 8% of total world output in the early 1960s, that figure fell to less than one half of one percent after the precipitous decline in copper production starting in the 1990s. Since 1999, copper mine production has registered eleven consecutive years of growth, reaching nearly 335 kt in 2008 as the DRC's share of world mine copper production edged higher to 1.4%. In 2010, copper mine production 497 kt and is likely to reach around 600 kt for the year, which would represent an annual increase of 20% (Figure 2.13).

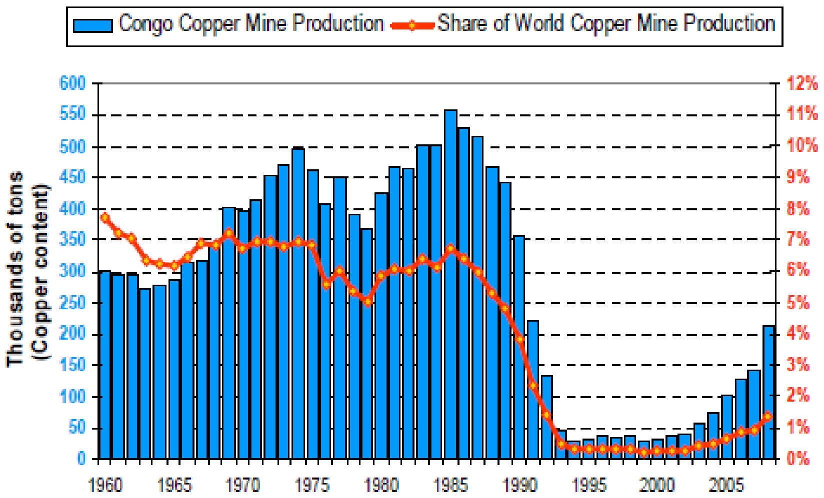

Figure 2.11: DRC's Copper production, Total and World share (1960-2010)
Source: ICSG Directory of Copper Mines and Plants - January 2010.

Copper Refinery production, as with mine production, plummeted in the DRC during the early 1990s (period of politic transition) and civil war years. From a peak of over 250 kt of refined copper production in 1988, refinery operations ground to a halt during the years 1997-2001. In recent years refinery output has been sharply increasing, from 36 kt in 2007 to 338 kt in 2009 as production increased.

In addition, based on the expansion plans in the copper sector in the DRC, total refined capacity in the DRC is forecast to increase up to 640 kt in 2013. This would elevate the DRC to the 9th largest mined copper producer and the 12th largest refined copper producer, by capacity, in the world (Pickard, 2010).

The forecast expansion of the Congolese copper industry would not only have substantial implications for the global copper market but also for the development of the Congolese economy and society. The extent to which the DRC can resolve the formidable challenges to the development of its copper sector and its ability to overcome the obstacles to economic development in general should move in tandem. This can be possible through appropriate policies (Wright and Czelusta, 2003).

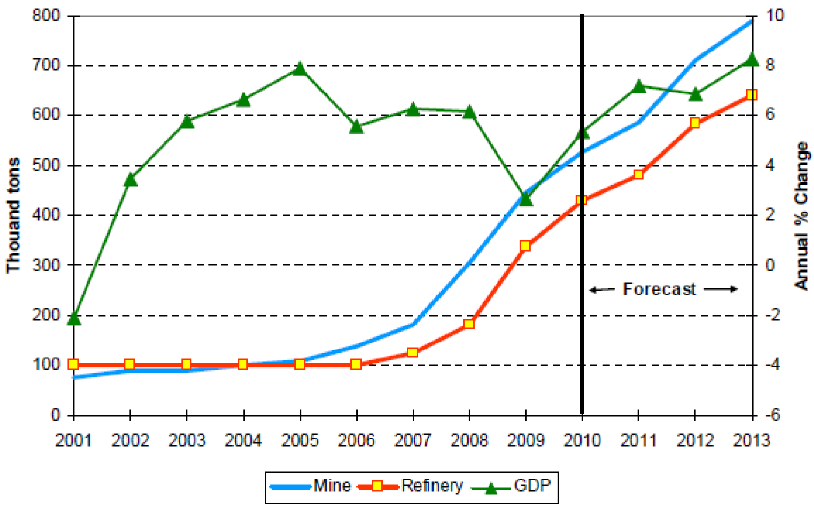

Figure 2.12: DRC's Mine and Smelter capacity and Real GDP Growth
Source: Ministry of mines (DRC), 2010

2.3.3 Government and mineral policy in the DRC

In the mid-1990's developing countries changed the mode from the State own companies to enter into partnership with the private sector following the advice and guidance of the World Bank.

The reason of changing were the difficult economic situation, the governments changes policies, laws and regulations to adapt them in the new world economic environment and the need of new investments to boost the vital sector for most of them. However, in the DRC, the changes came late due to the political situation explained in the previous pages.

In the DRC, the mining sector has been also facing a number of problems that have constrained its development. These include (a) a legal and regulatory framework not conducive to the development of the private sector; (b) serious transportation problems; and (c) chronic lack of investment.

After almost one decade of decline, DRC's mineral sector has rebounded significantly and is currently the main foreign exchange earner. Copper mining subsector is the principal activity within the mining sector. The spectacular reversal in mineral sector performance can be attributed to the adoption of World Bank recommendations in the new national mineral policy, as stated above, the new Mining Code 2002 and the Mining regulations 2003, aimed at revitalizing the sector. The government adopted new policies whereby it focuses on industry regulation and promotion, and the building of support institutions.

The World Bank additionally recommended that the government to leave mine operation, management, and principal ownership to the private sector. Since then, several new laws and policies have been enacted and implemented, and others are under consideration.

The mineral development is an integral part of the broader process of national economic development. David and Wright (2003) identify the following elements in the rise of the minerals economy: (1) an accommodating legal environment; (2) investment in the infrastructure of public knowledge; (3) education in mining, minerals, and metallurgy.

Since the mineral sector is no less linked to advances in knowledge and technological capabilities in the modern world, many resource-based economies have performed poorly, not because they have overemphasized minerals, but because they have failed to develop their mineral potential through appropriate policies. The mining sector can be progressively developed through exploration, technology progress, and investments in appropriate knowledge (Wright and Czelusta, 2003).

2.4 Energy sector in the DR Congo

Since independence in 1960, the power sector was liberal. Investments were mainly directed towards the development of industry sector and surrounding populations. Hence the imbalance of electricity supply throughout the provinces. There were three (3) private companies for generation (East Forces, Forces of Bas-Congo, Sogefor) and three (3) private companies for Distribution (Colectric in Kinshasa, Sogelec in Katanga , Cogelin in Kalemie).

In 1970, a national electricity company was created following the nationalization of all the six (6) previous private companies. Since then, the energy sector was dominated by the only publicly owned company, called SNEL (Societe Nationale d'electricite), which is dealing with hydroelectricity throughout the country.

This company was a vertically integrated monopoly. The State has an overall management control such as tariff setting, all procurements, foreign exchange transactions, investment decisions and programs, appointment of top managerial staff (Turkson and Rowlands, 1998).

- In the other hand, the State company “SNEL” was handling generation, transport , distribution, supply and commercialization of electricity in the Democratic Republic of Congo and export of electricity to neighboring countries. It regulates itself.

To fulfill this mandate, SNEL uses two types of grid, namely: The interconnected networks (three pools according to their location geographically: West, South and Easter network) and the isolated network systems due to the vastness of the country and the nearby hydroelectricity plants.

The dependence and intervention of the central government on: planning and management led to some negative results: The domestic supply network not completely well established; the disequilibrium between the Provinces on the establishment of the national supply network and the mismanagement by the government of the revenues (incomes) from energy export to neighboring countries;

Given the operational problems: Dwindling, aging production facilities, lack of spare parts and maintenance which result in lower activity of the national electricity company (SNEL) running today at 56 % of its installed capacity.[2]

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[2]Societe National d’Electricite (SNEL), Annual Report 2011.

2.4.1 Energy potential and generation

The Democratic Republic of Congo (DRC) is a country with abundant energy potential. DR Congo is endowed with a huge hydropower and a variety of energy types: from hydroelectricity to proven reserves of oil, coal, wood, uranium, natural gas, solar, agricultural biomass and geothermal energy. The energy resources up to date are summarized in table 2.6 and the national hydroelectric potential in figure 2.13. We should note that currently there are undergoing oil explorations activities in the western and eastern regions of the country by some Multinational Oil Companies (MOC).

Table 2.5: DRC's exploitable energy resources (CNE,2010)[3]

Resources	Exploitable Potential Reserves	Annual Product (P) Annual Consumption (P)
Hydro-electricity	774,000 GWh (100,000 MW) Installed power: ±2,500 MW	P: ±7,500 GWh C: ±5,000 GWh
Forestry	0,471 sq. miles (8.3 billion TEP)	C: 8,3 million TEP
Oil	More than 800 million barrels	P: 12 million
Gas	80 billion m^3	Unexploited
Coal	720 million tons	2005: P: 120,000 T C: 250,000 T
Uranium	NA	NA

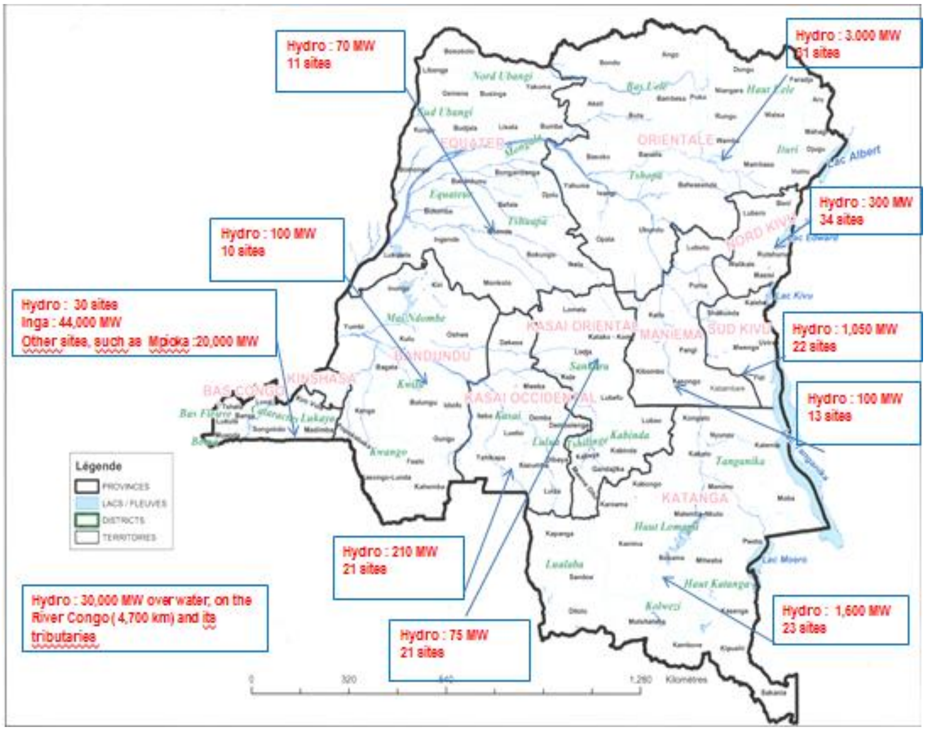

Figure 2.13: Hydroelectric potential of the DR Congo
Source: SNEL, 2011

[3]Commission Nationale de l'energie (CNE), Annual Report 2010.

Characteristics of the Energy situation in DRC

The country's current energy situation can be illustrated by some general indicators. Some indicators of the energy situation in DRC are:

1: Access to electricity

RDC's national rate of access to electricity is very low (11%) in comparison with the sub-Saharan Africa average, which is 30 percent. It should be noted that there is a need of intensive electrification as desired by energy policy. The development of new power generation infrastructures and facilities become essential especially in rural areas where this rate is less than 1% and could help improve substantially the energy situation and the economic growth.

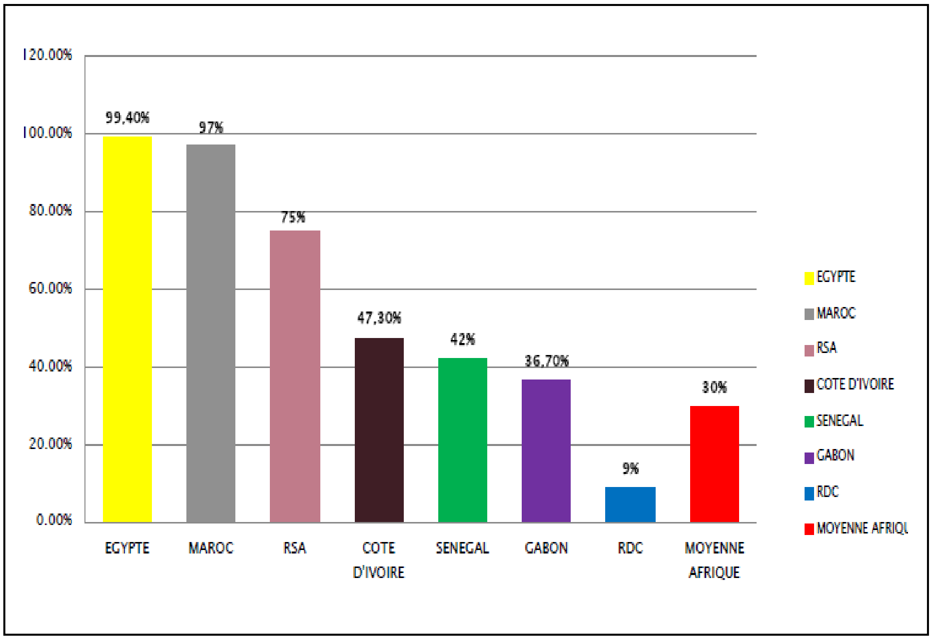

Figure 2.14: Selected African countries' rate of access to electricity
Source: WBI, 2010

2: Household electricity consumption

RDC's per capita electricity consumption is 103 kwh/capita which is 5 times less than the Sub Saharan African average (517 Kwh/capita) and 25 times less than the world's average which is 2,596 Kwh/capita).

The low value of the indicator is due to the fact that energy generation and supply does not follow population growth, a policy of readaptation should be conducted by the government throughout the energy sector. The low energy consumption in households, it is due to the electrical grids infrastructure. Not only those that exist are not maintained and equipped, but also they are no longer adapted to the fast growing of population (with an average rate of 3%), as well as the increasing energy demand in all other sectors of the economy.

3: Level of energy autonomy

The DRC depend totally on imports for its consumption of non-renewable energy (oil mainly in the form of crude oil and petroleum products), and the largest share of the latter is used in the transport sector.

The relationship between imports of non-renewable energy and total energy consumption shows a significant increase in the external energy demand since 1990. This indicates not only the country's energy dependence, but also its vulnerability to fluctuations in oil prices and the dollar rate. Local production should be intensified.

4: Quantity of energy produced by renewable sources

Hydroelectricity accounts for the largest proportion of energy generation (96 %) and other renewable sources are only present in the country in experimental form.

The Government launched this year after 25 years of inertia the building of three (3) hydropower generation: Kakobola, Grand Katende and Zongo 2. And up to 2015 the hydropower generation plant Inga III with a capacity of 3500 MW; Hydropower Busanga (240 MW) and Ruzizi III for whom the process of selection of Developers is underway will be on track.

The energy which has been declared "Priority of Priorities" in DRC, investment in this sector is priority number one for the Government and attention for a massive mobilization of funds required. That is why we need to analyse the relationship between energy consumption and economic growth in the DRC.

However, more than 50 years after independence, despite the abundance of energy resources in DR Congo, the reality is that there is a big gap between the demand and the supply of the final end-use energy, which are mainly electricity and fuels; and the state of art of the energy sector reveals a very low rate of energy supply to the citizens (CNE, 2010).

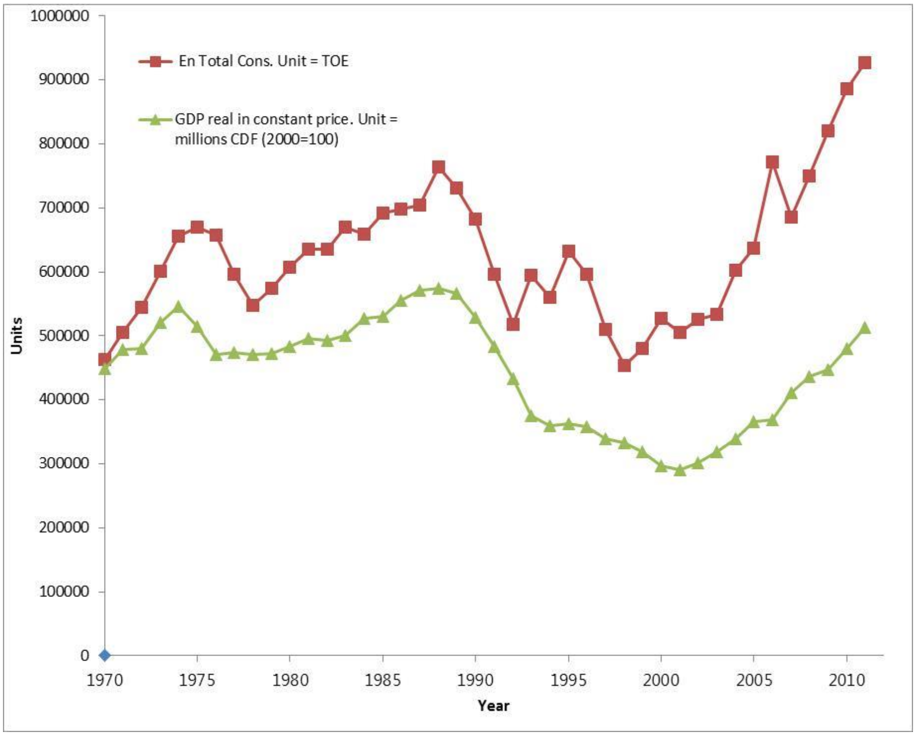

Figure 2.15: DRC's GDP and Energy total consumption (1970-2010)
Source: World Bank Indicators, 2011

DRC's economic has maintained a positive growth rate since 2002 and it is expected that this trend will continue in the years to come but the energy sector is not playing its vital role. Despite the fact that DRC has been a net electricity exporter to neighboring countries (Congo Brazzaville, Zambia, South Africa and Rwanda) since 1980s, a large part of the rural citizen still relies on non-commercial biomass energy sources.

The usage of energy in DRC is inefficient. For instance, in 2009, the energy intensity at constant price 2005 PPP) of the DRC was 99 kgOE/1000 US$., in comparison to the following countries : South Africa 312 KgOE, Zambia 467 KgOE; and Ivory Coast 317 KgOE ; Average Africa 310 KgOE (WBI, 2011).

DRC's per capita consumption of commercial energy still remains among the lowest in the South Saharan African region. Energy is historically known as a key factor in representing the economic and human development of every country (EIA, 2009).

2.4.1.1 Hydroelectricity generation

The hydropower generation corresponds to 56% of the installed capacity, and this is due to maintenance failure and management problems. There are 58 hydropower units and 52 thermal units in total throughout the country. Actually 25 thermal units are stopped (Snel, 2010). In DRC, the demand for energy is rapidly growing since 2001 more than the generation capacity generally from hydroelectric power plants, the input of thermal plant is insignificant and the country is experiencing an unprecedented electricity production shortfall as well as an electricity rationing causing great embarrassment to both residents and businesses.

The electricity is generated, transported, distributed and used with low efficiency while the personal use and loss rate is very high. The supply is not rational among all the users in urban areas. In rural areas, where the source of commercial energy supply is limited, the traditional non-commercial energy (wood, charcoal, and other agriculture by products) is mostly used for cooking (United Nations, 2010).

Table 2.6: DRC Electricity production (2006-2010)

Year	Generation (GWh)	Hydro Installed Capacity (MW)	Thermal Installed Capacity (MW)
2006	7,629	2,407	30
2007	7,543	2,407	18
2008	7,495	2,407	18
2009	7,665	2,407	18
2010	7,454	2,438	18

Source: SNEL, Annual Report 2010

Table 2.7: DRC Electricity supply & export (2006-2010)

Year	Generation (GWh)	Supply (GWh)	Export (GWh) to Neighboring Countries	Loss* (GWh)
2006	7,629	4,626	1,190	764
2007	7,543	5,742	1,359	1565
2008	7,495	5,697	674	1636
2009	7,665	6,104	480	1100
2010	7,454	6470	522	323

Note: (*) loss in transportation lines and distribution network
Source: SNEL, Annual Report 2010

2.4.1.2 Energy supply

DRC's total primary energy supply (TPES) in 2010 was 22,921 kilotons of oil equivalent (ktoe), where the total final energy consumption was 22,412 ktoe (Table 2.8). Despite the abundance of divers energy resources in

DR Congo (Table 2.6) the DRC has been relying only on hydroelectricity but nowadays the government is actively promoting other source likes oil and gas to prevent the DRC's energy supply system highly vulnerable against any shock in the world energy market, when there is an oil supply disruption due to geopolitical conflicts. Active exploration have been done in the central cuvette and currently exploration activities have already started in Easter Province (the Albertine Graben) and shorltly in the Graben of Tanganyka in the Easter part of the DRC for oil and gas.

With the rapidly increasing energy demand due to the increase of population (rate 3% per year) and the relaunching of industrial activities specifically in the mining sector, it is projected that by 2025 the rate of access of the population to electricity will reach 60% such as gradually improve of 19%, 33% and 60% by 2015, 2020 and 2025 respectively. In the meantime the government is considering the expansion and construction of new hydroelectric power generation in each province (SNEL, 2011).

Table 2.8: Energy balance for the DRC (IEA, 2010)

Primary Energy Supply (ktoe)		Final Energy Consumption (ktoe)	
Indigenous production (ktoe)	23,346	Industrial sector	4,990
Import	779	Transport sector	227
Exports	-1,117	Other	17,164
		Residential	16,871
		Non-specified	275
Total PES	22,921	Total FEC	22,412
Coal	296	Coal	249
Crude oil	3	Crude oil	0
Oil products	538	Oil products	586
Natural gas	7	Natural gas	0
Hydro (TWh)	670	Hydro (TWh)	572
Biofuels & waste	21,473	Biofuels & waste	21,006

2.4.2 Energy policy

2.4.2.1 Past Energy policy Situation

Since 1960s, supplied –oriented energy policy by the government;

1970: organization of the energy sector since 1960, Creation of SNEL

Dependence and intervention of the central government on: planning and management led to some negative results: The domestic supply network not completely well established; Disequilibrium between the Provinces on the establishment of the national supply network; Mismanagement by the government of the revenues (incomes) from energy export to neighboring countries; Given the operational problems : Dwindling, aging production facilities, lack of spare parts, etc.: Result in lower activity of SNEL (running at 40 % of its installed capacity). In 1990s: Liberalization of the energy sector to improve the energy production but this process was delayed due to political instability in the country.

Energy sector liberalization

The DRC Government decided to liberalize the energy sector in 1991 but the delay was due to political instability that experienced the country. The basic purpose of the liberalization of this sector is to increase efficiency of the energy sector through facilitating market competition.

The liberalization process is encompassing several policy measures such as restructuring of the energy sector, opening up to introduce competition and removing other controls. Some examples of the specific policies are: creating separate entities for generation, transportation and distribution in the electricity sector, allowing private sector entry, energy pricing, fuel use, fuel import, and capacity expansion etc. Therefore institutional measures such as setting up independent regulatory bodies is a requirement for success of these policy actions.

2.4.1.2 Policy reform and Strategy

The major over-reaching objectives of the government Policy were spelled out in the New Energy Code**,** a bill currently in the legislative process and the aim is to achieve the following:

- To guarantee adequate, reliable and sustainable energy supply at appropriate costs and in an environmentally friendly manner;
- Ensure the development of the country's energy resources, with diversification option for enhanced achievement of national security;
- To accelerate the liberalization of the energy sector: to improve efficiency of existing power plants, to attract private capital, to rehabilitate existing plants , upgrading some of them and build new

power plants.

For that DRC must keep regular growth of energy supply to boost the growth of its economy output. The recent agreements concluded to date between private partners in the mining sector of DRC with the national electricity company for funding energy project so as to meet their need for mining operations is among government investment policies in the energy sector (SNEL, 2012).

The ongoing reform of the legal and institutional framework of the energy sector includes six components: Enlargement of the institutional framework; Liberalization of this sub sector and opening of the electricity market to private (the state of monopoly of SNEL disappears automatically); Advocates the principle of remunerative tariff, access to the transport network to all operators of the sector ; Specification of legal system and access conditions in the sub-sector; Establishment of an Independent Electricity Regulatory Authority and Establishment of a National Electrification Agency.

The sector of energy is managed by two ministries: the Ministry of Hydraulic resources and Electricity and the ministry of hydrocarbons and gas. Both of them are responsible for sectorial management, formulation of laws, policy framework and strategies, master plans, etc.

Chapter 3. Literature Review

3.1 Literature on energy consumption and economic growth

The debate regarding the relationship between energy consumption and economic growth, has attracted vast literature in recent years and has important implications from the theoretical, empirical and policy standpoints.

Since the seminal paper of Kraft and Kraft (1978), which supported the unidirectional causality from economic growth to energy consumption in the USA for the period from 1947 to 1974, the causal relationship between energy consumption and economic growth has been extensively examined in the literature using different techniques and different samples of countries. The empirical outcomes of these studies have been varied and sometime found to be conflicting.

The causal relationship between energy consumption and economic growth can be broken down into four testable hypotheses. First, ''*the growth hypothesis*'' suggests that energy consumption plays an important role in economic growth directly and/or as a complement to labor and capital in the production process. It implies that economic growth is dependent on energy consumption, and a decrease in energy consumption may restrain economic growth. In this context, energy conservation policies which reduce energy consumption may have an adverse impact on economic growth.

Second, called *''the conservative hypothesis''*, argues unidirectional causality from economic growth to energy consumption. It suggests that energy conservation policies may have little or no impact on economic growth.

The conservative hypothesis is supported if an increase in real GDP causes an increase in energy consumption.

The third ‘‘*neutrality hypothesis*’’, argues that there is no causality between energy consumption and economic growth. In other words, both energy consumption and economic growth are neuter with respect to each other. In this case, the reduction in energy consumption through energy conservation policies will not impact economy growth.

Finally, the ‘‘*feedback hypothesis*’’ suggests that there is bidirectional causal relationship between energy consumption and economic growth reflecting the interdependence and possible complementarities associated with energy policies and economic growth.

This complementary relationship opens the possibility that energy conservation policy which reduces energy consumption may impact economic growth. Likewise, such fluctuations in economic growth may very well be transmitted back to energy consumption.

Previous empirical studies on energy consumption and economic growth for developed and developing countries provide mixed results. The main reason for the discrepancy in results in the previous research comes from the use of different econometric methods, divergence across countries, time horizon, differences in variable selection and model specifications.

The majority of these studies on the causality between energy consumption and economic growth have mainly used the cointegration test associated with Engle and Granger (1987) and the maximum likelihood test based on Johansen (1988) and Johansen and Juselius (1990).

Asafu-Adjaye (2000) examined the causal relationship between energy consumption, energy prices and economic growth for India, Indonesia, the Philippines and Thailand, using cointegration and error-correction modeling techniques. They show that, in the short-run, unidirectional Granger causality is found between both series for India and Indonesia while bidirectional causality running from energy consumption to income for Thailand and the Philippines.

Yang (2000) uses different types of energy consumption (oil, gas, coal, power) to test for the causal relation with GDP in Taiwan. He uses yearly data for the period 1954.1997 to conclude that different directions of (Granger) causality exist between GDP and various kinds of energy consumption.

Glasure (2002) employs a five-variable vector ECM to study the (Granger) causality between GDP and energy consumption in Korea. Government expenditure is used as a proxy for government activity, money supply is used as a proxy for monetary policy and oil prices are also included as an important factor in explaining the causality. The period 1961.1990 is considered. Structural breaks of two oil price pikes are further included as dummies in the model. He derives a bi-directional causation, and the oil price is found to have the biggest impact on economic growth and energy consumption.

Oh and Lee (2004) also study data on Korea, but shift the data set one decade ahead to consider the period 1970 - 1999. They follow an approach that is more based in the classic production function literature (which is also propagated by Stern (1993)). Besides energy, labour and capital are also considered to be important production factors for generating GDP. They correct for quality improvements in energy by using a mean price weighted log Divisia index to establish the level of energy use in the economy. Following Glasure (2002), they also use a vector ECM and confirm the conclusion of bi-directional causation between energy and GDP.

Yu and Jin (1992) use employment as a third variable in explaining the link between energy consumption and GNP. They use monthly data over the period 1974:1.1990:4 for the US and they do not find any evidence for co-integration. With this analysis they find support for earlier conclusions that energy restrictions do not harm economic growth in the US and that energy conservation has no clear impact on employment.

Moroney (1992) argues that energy is a very important production factor. The oil crises in the 70s and 80s revealed this. The influence is more than just a minor expenditure of GDP. Stern (1993) in his extensive review of the literature stresses that economic growth is not only a product of input factor energy use, but input factors labour and capital also play an important role. He argues that the aggregation of labour and energy is problematic. It does not account for quality differences in labour, which can range from unskilled to specialists jobs.

Also, an mtoe (million tonne of oil equivalent) of coal may not be as efficient as an mtoe of electricity. Ideally variables need to be developed to account for these quality differences in labour and energy, for instance, by using salaries and energy prices. Stern (1993) shows that the classic measure of energy consumption does not give evidence for causality, while his corrected measure does. He uses annual data over the period 1947.1990 for the US to establish this result. In a similar framework Stern (2000) undertakes a co-integration analysis to conclude that energy is a limiting factor for growth, as shocks to energy tend to reduce output.

In a two country study for data from 1960 to 1984 and from 1960 to 1981 for Nigeria and Tanzania respectively, Ebohon (1996) shows a simultaneous causal relationship between energy and economic growth for Nigeria and Tanzania employing Granger causality test.

Applying cointegration and error correction vector techniques on data for Malawi from 1970 to 1999, Jumbe (2004) found a bidirectional causality between electricity consumption and economic growth, but a unidirectional causality running from non-agricultural GDP to electricity consumption.

Hondroyiannis et al (2002) study the link between energy consumption, GDP and the Consumer Price Index (CPI) for Greece. They consider annual data over the period 1960-1996. They find evidence for long-term bi-directional causality between energy consumption (total and industry) and GDP, while there is no causality between residential use of energy and GDP. This means that demand for residential energy is exogenous and merely unrelated to the level of GDP growth.

Sari and Soytas (2004) apply a so-called generalized forecast error variance decomposition technique, which they use to shed light on the link between energy consumption and economic growth. They conclude that energy consumption is almost as important as employment in explaining the variance in the growth of national income in Turkey.

Soytas et al (2001) also study the causality between energy consumption and GDP for Turkey, using a cointegration analysis. They use annual data over the period 1960-1995 from the International Energy Agency and transform these data with logarithms. They, in contrary to the conclusion we derive in this paper, draw the conclusion that energy consumption unidirectionally Ganger-causes GDP. The reasons for this opposite are manifold.

The period of the used data differs, the data source differs (the difference between data from the Turkish Ministry of Energy and Natural Resources and IEA is considerable), and they use a log transformation, while we do not. Finally, data prior to 1970 are problematic as there is a structural break in the data.

Altõnay and Karagöl (2004) apply a series of so-called unit root and causality tests to verify whether there is a causality between GDP and energy consumption for the period 1950-2000. Establishing that energy consumption causes GDP has important policy implications, because then a reduction in energy consumption will translate into a break on economic growth. While they show that energy consumption and GDP in Turkey do have a unit root, they also find a structural break in the data. They conclude that there is no causality between energy and GDP.

Belloumi (2009) applied Johansen cointegration technique to assess the causal relationship between per capita energy consumption and per capita gross domestic product for Tunisia during the period 1971–2004. These results show a long-run bidirectional causal relationship between the two series and a short-run unidirectional causality from energy to gross domestic product. But the problem with most existing time series studies is that they are based on bivariate causality tests, which have been shown to suffer from omitted variable problems and lead to erroneous causal inferences (see Caporale and Pittis, 1995).

Following advances in time series analysis in the last decade, recent investigations of the energy consumption and economic growth relationship have carried out the Granger causality test of Toda and Yamamoto (1995) to examine the relationship between energy consumption and economic growth. For instance, Wolde-Rufael (2005) applied this approach to analyze the causal relationship between energy consumption and economic growth in a 19 country study of Africa.

The results show that there is evidence for a long-run relationship for only 8 of the 19 countries and a short-run causality for 12 countries. Similarly, in a multivariate causality test, Akinlo (2008) found conflicting results for 11 African countries. Wolde-Rufael (2006) found evidence of a unidirectional causality running from economic growth to energy consumption in 5 African countries, whereas bidirectional causality was found for 2 countries and no evidence for causal relationship in 7 African countries.

Odhiambo (2009) found that there is a unidirectional causal relationship running from energy consumption to economic growth for Tanzania. Wolde-Rufael (2009) reassessed the relationship between energy consumption and economic growth using 17 countries in Africa. He has taken into account labor and capital as additional variables.

The results of his multivariate modified Granger causality analysis tend to reject the neutrality hypothesis for energy– income relationship in African countries. In contrast, results of variance decomposition analyses show that in 11 out of the 17 countries, energy was not even the second most important factor to output growth; capital and labor are the most important factors in output growth in 15 out of the 17 countries.

Odhiambo (2010) re-examined the causal relationship between energy consumption and economic growth in three sub-Saharan African countries. He added the prices as an additional variable because of its effects on both energy consumption and economic growth. Indeed, an increase in prices is expected to lead to a decrease in energy demand, thereby leading to a decrease in energy consumption. On the other hand, an increase in prices leads to a decrease in energy demand, thereby leading to a contraction in aggregate output.

He discovered that the causality between energy consumption and economic growth varies significantly across the three countries. The results indicated that for South Africa and Kenya there is a unidirectional causal relationship from energy consumption to economic growth while for Congo (DRC) it is economic growth that drives energy consumption. Similarly, Ouedraogo (2010) found that there is evidence of a positive feedback causal relationship between electricity use and real GDP for Burkina Faso.

As it can be seen, a general conclusion is that the results are still mixed to date: that is, while some studies find causality running from energy consumption to economic growth, others figure out causality running from economic growth to energy consumption and even some other studies suggest no causality and /or bidirectional causality between these two variable. Hence, one should be cautious with empirical results and explain them while taking into account each country's characteristic.

3.2 Literature on primary export and economic growth

Economic growth and its related factors, both theoretical and experimental aspects have been considered economists and policy makers of countries. Also, more than two decades the relationship between exports and economic growth has been had special importance. (Medhi and Shahryar, 2012)

According to the commandment Schumpeter, growth is the following slow changes and gradual in economic conditions in the long-term is caused result of gradual increase in savings rates and population. Opinions Schumpeter about economic growth has been widely accepted by neoclassical economists.

In DRC such as other countries, growth and achieve the high rate is one of the goals of government. Hence review factors impact on growth including commodities exports can be the way for economic policy maker's framework intended purpose.

Shan and Sun (1998) studied causal relationship between exports and growth the using time-series data of 1996-1978 in Hong Kong, Korea and Taiwan by VAR method and they have used the Matrix model. Their results showed that there is a two-way relationship between exports and economic in Hong Kong and Korea but for Taiwan lead to economic growth only by export.

Vohra (2001) examined the role of export-growth linkage in India, Pakistan, the Philippines, Malaysia, and Thailand on the basis of time series data from 1973 to 1993. The empirical results indicate that exports have a positive and significant impact on economic growth when a country has achieved some level of economic development. The result also signifies the importance of liberal market policies by pursuing export expansion strategies and by attracting foreign investments.

Hamuda, Elbeidi and Gazda (2010) studied the relationship between export and economic growth the using time-series data of 1980-2007 in Libya Arabic Union. Results showed that in the short term export growth has positive effect on Gross Domestic product (GDP) growth. Export, GDP and exchange rate are converging and there is long-term bilateral relationship between export and GDP growth.

Pandey (2006) in his article reviewed export and Economic Growth by causality relationship the using time-series data of 1950-2002 in India. Result show that in short term there is bilateral relationship between exports and GDP and in the long term exports and GDP aren't convergent in constant prices but are convergent in current prices.

Jordam (2007) in his article studied exports and Economic Growth the using time-series data of 1970-2005 in Namibia. The result showed that exports in the short term lead to economic growth. Also, there is positive long-term relationship between exports and economic growth.

In addition to the vast literature on natural resources and growth, there are some specific studies on copper and Chilean economic policy that consider both long-term and business cycle issues. Papers that focus on the long-term effects of copper include: Morande´ and Quiroz (1996), Bande and Ffrench-Davis (1989), Romaguera and Contreras (1995), and Moguillansky (1998).

Morande´ and Quiroz (1996) consider the long-term effects of the mining sector on the real exchange rate, wages, and fiscal revenues. By analyzing the experience of the early 1990s, they conclude that copper has had a modest effect on the real appreciation of the exchange rate and increase in wages, but negligible effects on inflation. Furthermore, they notice that the mining industry is capital-intensive and that capital is largely imported, so that local resources are not displaced and the possibility of a Dutch disease is very small.

Additionally, copper brings considerable resources to Chile's Treasury. The authors conclude that copper is a full-blessing and that any significant intervention by government authorities to try to counterbalance the small negative effects in some sectors would likely bring harmful side effects.

Bande and French-Davis (1989) find that copper contributed to the downturns of late 1974 and 1981, while the price upturn of 1987–89 was a determinant for the sharp recovery that took place in that period. They notice that the main objective of public policies on copper between 1973 and 1988 was to expand production and to set up appropriate mechanisms to offset the economy’s external vulnerability. They argue that, while the first objective was partially met, the second objective has not been reached because of the excessive reliance on market mechanisms to counteract fluctuations of the copper price.

Romaguera and Contreras (1995) study the impact of copper in the context of structuralist analysis and conclude that copper price cycles have had an important effect on Chilean growth in the last 40 years by determining the external and fiscal constraints. They also argue that huge fluctuations of copper prices have made fiscal revenues and availability of foreign currency unstable and have had negative consequences on growth in the long run.

Moguillansky (1998) focuses on investment in the mining sector. She argues that the institutional framework (the law on foreign investment (1974) and the law on mining (1980)) created the necessary conditions for the increase of copper production in the early 1990s. She also finds evidence that foreign investment in the copper sector has had a positive effect on the national mining company (CODELCO), which invested heavily in the beginning of the 1990s to maintain efficiency.

Spilimbergo (2000) study the links between world copper price and the chilien economy, concluded that copper prices are important for short-term economic fluctuations. While many mechanisms can be at work, investment seems to play a major role. During periods of high copper prices, both internal and external factors favor investment. Internally, lower current account deficits lead to less stringent monetary policy.

Externally, international investors are attracted by enhanced long-term external stability. Additionally, high copper prices and capital inflows have typically created upward pressure on the real exchange rate in the first phase of the copper cycles.

Although the papers reviewed use different frameworks (neoclassical or structuralist), different methodologies (time series analysis and case studies), and different periods of analysis, they all reach the conclusion that copper has played a crucial role in the Chilean economy. However, there is no agreement on which is the main transmission mechanism from copper to the Chilean economy.

In recent years, an interesting conclusion concerning mineral demand and economic development has reached by comparing intensity of resources used with the level of economic development (e.g Tilton,1990; Chang,1993). The relationship between copper consumption per dollar of GDP and GDP growth has been investigated by Nishiyama (1996). The discussion was routed in changes in resource requirements during different levels of economic development such as industrialized countries, newly industrialized countries, and developing countries. The main findings were: At an early stage of economic development based on non mechanized agriculture, per capita income levels and material requirements are low. As industrialization progresses, manufacturing capabilities move from light industry, which used unskilled labor and simple technology, to heavy industry, which required skilled labor and more sophisticated technology. At a later stage, consumer demand s shift from manufactured goods to services. The service sector is less material-intensive than the manufacturing sector. The relationship between the intensity of the resource use and per capita income follows an inverted U-shaped curve. (Radetzki and Tilton, 1990).

Chapter 4. Methodology and Analytical Framework

4.1 Introduction

Many economists agree that time series data need to be analyzed using time series econometric techniques because of the dynamic effect of the series. To test for the causal linkage between energy consumption and economic growth and/or between other variables in the short run, in the long run, and overall, three steps are commonly followed in time series approach studies: (1) testing for unit roots and the order of integration; (2) testing for cointegration between the series; and (3) causality testing.

Balke and Flomby (1977) stated that the concept of cointegration is used to capture the notion that non-stationary variables may nonetheless possess long-run equilibrium relationships and thus have a tendency to move together in the long run. According to Engler and Granger (1987), a linear combination of two or more non-stationary series that have the same order of integration may be stationary. If such stationary linear combination exists, the series are considered cointegrated, and long-run equilibrium relationships exist among them. Therefore, cointegration tests must be taken when analyzing the long-run relationship between economic growth and other variables.

In this study, the econometrics procedure was used, following the steps below, taken mostly from Enders (1995). All the three steps were taken in this study for the following reasons: to ensure that all the variables included in the study were stationary either in level or in first difference (unit root tests), to look into the possibility of the existence of long-run relationships between the integrated variables (cointegration test), and to determine the direction of causation between GDP and each of the chosen variables. Below is a summary of each step.

For the causality test, the test of stationarity of variables was done first to decide if the standard Granger causality test could be applied. If the datasets proved to be stationary, then the standard VAR Granger causality test was applied, but if they proved to be non-stationary, the first difference was proceeded with, which means that the non-stationary variables were converted to stationary data.

Thereafter, it was checked if the variables were cointegrated. If it was shown that the variables were cointegrated, then the Granger causality test based on the vector correction model (VECM) was used to check the causality between these variables; otherwise, if they were not cointegrated, the VAR model was used in the first difference.

Analysis Flowchart

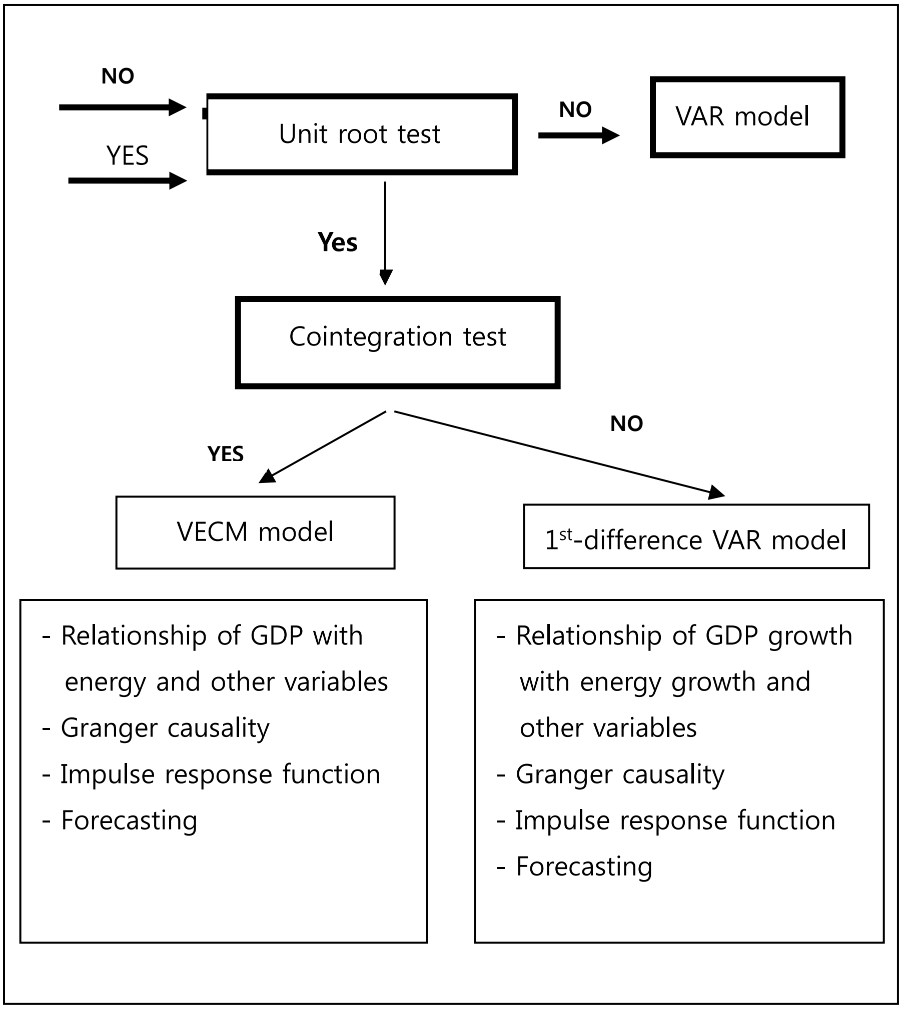

Figure 4.1: Flow of analysis for all the variables
(energy consumption, economy growth, copper production, and copper price in DRC).

4.2 Econometric methods

As has been mentioned, in this study, the econometrics procedure that was used involves the following steps mostly taken from Enders (1995). All the three steps were taken in this study, for the following reasons: to ensure that all the variables included in the study were stationary either in level or in first difference (unit root tests), to look into the possibility of the existence of long-run relationships between the integrated variables (cointegration test), and to determine the direction of causation between GDP and each of the chosen variables. Below is a summary of each step.

4.2.1 Unit root tests

A test of stationarity (or non-stationarity) that has become popular over the past several years is the unit root test. Its starting point, the unit root (stochastic process), will first be explained, starting from

$$y_t = \rho y_{t-1} + \mu_t, \qquad -1 \leq \rho \leq 1 \tag{1}$$

where μ_t is a white-noise error term. It is known that if ρ=1, in the case of the unit root, equation (1) becomes a random-walk model without drift, which is known to be a non-stationary stochastic process. Therefore, if y_t is regressed on its one-period lagged value y_{t-1}, it can be determined if the estimate ρ is statistically equal to 1. If it is y_t, then it is non-stationary. This is the general idea behind the unit root test of stationarity.

Equation (1) cannot be estimated via OLS, and the hypothesis that ρ=1 cannot be tested through the usual t-test because that test is severely biased in the case of the unit root. Therefore, equation (1) is manipulated by subtracting y_{t-1} from both sides of equation (1) to obtain the following equations:

$$\begin{aligned} y_t - y_{t-1} &= \rho y_{t-1} - y_{t-1} + \mu_t \\ &= (\rho - 1) y_{t-1} + \mu_t \end{aligned} \tag{2}$$

which can be alternatively written as

$$\Delta y_t = \delta y_{t-1} + \mu_t \qquad (3)$$

where δ=(ρ-1) and Δ, as usual, is the first-difference operator.

In practice, therefore, instead of estimating equation (1), equation (2) is estimated, and the null hypothesis δ=0 is tested, the alternative hypothesis being δ<0 as δ=(ρ-1) for stationarity ρ must be less than one. For this to happen, δ must be negative.

If δ=0, then ρ=1, and there is a unit root, meaning the time series under consideration is non-stationary.

Note that if δ=0, equation (3) will become

$$\Delta y_t = (y_t - y_{t-1}) = \mu_t \ .$$

As μ_t is a white-noise error term, it is stationary, which means that the first differences of a random-walk time series are stationary.

Dickey-Fuller Test (1979)

In the related literature, the tau statistic or test is known as the Dickey-Fuller (DF) test, in honor of its discoverers (Gujarati & Porter, 2009). The DF test is estimated in three different forms, under three different null hypotheses.

Y_t is a random walk: $\Delta y_t = \delta y_{t-1} + \mu_t$ (3)

Y_t is a random walk with drift (intercept): $\Delta y_t = \alpha_1 + \delta y_{t-1} + \mu_t$ (4)

Y_t is a random walk with drift around a deterministic trend:

$$\Delta y_t = \alpha_1 + \alpha_2 t + \delta y_{t-1} + \mu_t \qquad (5)$$

where *t* is the time or trend variable. In each case, the hypotheses are:

Null hypothesis: Ho: δ=0 (there is a unit root, or the time series is non-stationary, or it has a stochastic trend); and

Alternative hypothesis: H1: $\delta<0$ (the time series is stationary, possibly around a deterministic trend).

It is worth noting that the DF test does not consider the autocorrelation and heteroscedasticity issues.

Although the traditional regression models assume that both the dependent and independent variables are stationary and that the errors have mean zero and constant variance, a common concern with the standard regression models is the presence of unit roots in the series because most economic time series normally behave with the stochastic trends. With evidence of unit roots, the series are said to be intergraded of order one—I(1), meaning that they must be modeled in first differences ($\Delta y_t = y_t - y_{t-1}$) to make them stationary. A time series is stationary if it does not change over time, which implies that its values have constant variability.

Overall, with evidence of non-stationary variables such as those in time series analysis, the data might present spurious regressions. Thus, unit root tests account for the possible correlation of unit roots in the first differences in the time series. These tests allow for the presence of a nonzero mean and a deterministic linear time trend. Two of the wildly used unit root tests were also applied to this study: the ADF and Phillips-Perron (PP) tests.

The Augmented Dickey-Fuller (ADF) Tests

The ADF test is a modified version of the DF methodology, and considers autocorrelation. In conducting the DF test as in equations (3), (4), and (5), it was assumed that the error term *ut* was uncorrelated. In case the μ_t were correlated, however, the augmented Dickey-Fuller (ADF) test, another test developed by Dickey and Fuller, was applied. This test is conducted by augmenting the preceding three equations by adding the lagged values of the dependent variable Δy_t. The error terms in all three equations are assumed to be independent (white noise), with equal variance. All three equations are denoted as ADF tests. Below is a presentation of the three modified equations of DF.

$$\Delta y_t = \delta y_{t-1} + \sum_{i=1}^{p} \beta_i \, \Delta y_{t-1} + \mu_t \tag{6}$$

$$\Delta y_t = \alpha_1 + \delta y_{t-1} + \sum_{i=1}^{p} \beta_i \, \Delta y_{t-1} + \mu_t \tag{7}$$

$$\Delta y_t = \alpha_1 + \alpha_2 t + \delta y_{t-1} + \sum_{i=1}^{p} \beta_i \, \Delta y_{t-1} + \mu_t \tag{8}$$

where *t* is the time or trend variable and μ_t is a pure white-noise error term.

If null hypothesis: Ho: $\delta=0$, the time series is non-stationary; and

If alternative hypothesis: H1: $\delta<0$, the time series is stationary, and the lower-tail critical value is used as the critical value, the one-sided p-value in macKinnom (1996) was used in this study.

The last two equations were used to test for unit roots in the series selected for this study. If these null hypotheses were rejected in the series selected for this study, then the series contains unit roots, and the order of integration I(d) was decided. Failing to reject these null hypotheses implied that the series in levels were non-stationary and must be modeled in first differences — I(1)— to make them stationary. Rejecting these hypotheses (calculated t-statistics greater than the critical values) implied that the series were stationary and must be modeled in levels (actual data).

Phillips-Perron (PP) Tests

The Phillips and Perron (1988) test for unit roots is a modification and generalization of DF's procedures. While the DF test assumes that the residuals are statistically independent (white noise) with constant variance, the PP test considers less restriction on the distribution of the disturbance term (Enders, 1995).

The PP test undertakes non-parametric correction to account for the autocorrelation present in the higher-AR-order models. The test assumes that the expected value of the error term is equal to zero, but the PP test does not require the error term to be serially uncorrelated. The critical value of the PP test is similar to that given for the DF test.

The Stata software has an option that automatically selects the lag length on AKaike, Schwarz, and other information criteria.

4.2.2 Cointegration test: Johansen's procedure

The time series has to be examined for cointegration. Cointegration analysis helps identify long-run economic relationships between two or several variables, and to avoid the risk of spurious regression. The cointegration test is conducted to find out whether non-stationary data are cointegrated or not. Cointegration analysis is important because if two non-stationary variables are cointegrated, a VAR model in the first difference is misspecified due to the effect of a common tend. If a cointegrating relationship is identified, the model should include the residuals from the vectors (lagged one period) in the dynamic vector error-correcting mechanism (VECM) system.

There are various approaches that can be used to test for cointegration, such as the Engle and Granger approaches and the Johansen and ARDL bounds testing approaches. In this study, the Johansen (1988) cointegration test was used to identify cointegrating relationships among the variables. Within the Johansen multivariate cointegrating framework, the following system is estimated:

$$\Delta Z_t = \Gamma_1 \Delta Z_t + \cdots + \Gamma_{k-1} \Delta Z_{t-k-1} \Pi Z_{t-1} + \mu + \varepsilon_t \ : t = 1, \ldots, T \quad (9)$$

where Δ is the first-difference operator; z' denotes a vector of variables, ε_t~n iid $(0,\sigma^2)$; μ is a drift parameter; and Π is a (pxp) matrix of the form $\Pi=\alpha\beta'$, where α and β are both (pxr) matrices of full rank, with β containing the r cointegrating relationships and α carrying the corresponding adjustment coefficients in each of the r vectors.

The Johansen approach can also be used to carry out Granger causality tests. In the Johansen framework, the first step is the estimation of an unrestricted, closed p-th-order VAR in k variables. Johansen (1988) suggested two test statistics to determine the cointegration rank: the trace statistic test and the maximum eigenvalue test (Balaguer & Jorda, 2002).

In the trace statistic test,

$$\mathrm{N}\{\mathrm{trace}(^{r_0}/_{k})\} = -\mathrm{T} \sum_{i=r_0+1}^{k} \ln\left(1 - \hat{\lambda}_i\right) \quad (10)$$

where $\hat{\lambda}_i$ are the estimated eigenvalues $\lambda_1 > \lambda_2 > \lambda_3 > \ldots > \lambda_k$ and r_0 ranges from zero to k-1 depending on the stage in the sequence. This is the relevant test statistic for the null hypothesis $r \leq r_0$ against the alternative $r \geq r_0+1$.

The maximum eigenvalue test, known as λ_{max}, is denoted as $\lambda_{max(r_o)}$. This is closely related to the trace statistic test but arises from changing the alternative hypothesis from r≥ro+1 to r=ro+1. The idea behind it is to try to improve the power of the test by limiting the alternative to a cointegration rank that is higher by just one rank than that of the null hypothesis. The λ_{max} test statistic is

$$\lambda_{\max(\ r_0\ )} = -\mathrm{T} \ln{(1 - \lambda_i)} \text{ for } i = r_0 + 1 \tag{11}$$

The null hypothesis is that there are r cointegrating vectors, against the alternative of r+1 cointegrating vectors. Johansen and Juselius (1990) indicated that the trace test might lack power relative to the maximum eigenvalue test. Based on the power of the test, the maximum eigenvalue test statistic is often preferred.

4.2.3 VAR models and lag length selection

The VAR models were developed as modeling tools in the early 1980s and originated from the concerns about the validity of some of the assumptions used in traditional macroeconometric models. In particular, Sims (1980) argued that the restrictions used to identify the parameters in the traditional models, which often took the form of excluding variables or their lags from equations or assuming that a particular variable was exogenous, were "incredible."

Estimating a VAR involves choosing which variables to include in the system, and deciding on the number of lags. The results obtained can be sensitive to both of these choices. The number of lags is usually determined based on statistical criteria[4] (e.g., sequential-likelihood ratio tests, Akaike/ Schwartz information criteria), and the variable selection is done based on the economic theory.

4.2.4 Granger causality test

Cointegration implies that causality exists between two variables, but it does not indicate the direction of the causal relationship.

Engle and Granger (1987) stated that if several variables are all I(d) series, their linear combination may be cointegrated; that is, their linear combination may be stationary. Although the variables may drift away from equilibrium for a while, economic forces are expected to restore it. Thus, they tend to move together in the long run irrespective of short-run dynamics.

The definition of Granger causality is based on the hypothesis that X and Y are stationary or I(0) time series. Therefore, the fundamental Granger method for variables of I(1) cannot be applied. In the absence of a cointegration vector, with I(1) series, valid Granger causality test results are obtained by simply first-differentiating the VAR model.

With cointegration variables, Granger causality will require the further inclusion of an error term in the stationary model to capture the short-term deviations of series from their long-term equilibrium path, the so-called *VECM*. The difference between the two models is that the VAR model does

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[4]Such as sequential-likelihood ratio tests or Akaike/Schwartz information criteria

not include an error correction term in the equation (Carter et al., 2008).

4.3 Theoretical VAR-D models

Hassapis et al. (1999) showed that in the absence of cointegration, the direction of causality can be decided upon via standard F-tests in the first-differenced VAR. An F-test is carried out for the null hypothesis of no Granger causality, where the F statistic is the Wald statistic of the null hypothesis. If the F statistic is greater than a certain critical value for an F distribution, then the null hypothesis that Y does not Granger-cause X is rejected, which means that Y Granger-causes X.

The VAR model in the first difference can be written as

$$\Delta y_t = \alpha_1 + \sum_{i=1}^{p} \beta_i \, \Delta y_{t-1} + \sum_{j=1}^{p} \rho_j \, \Delta x_{t-j} + \mu_{1t} \quad (12)$$

$$\Delta x_t = \alpha_2 + \sum_{i=1}^{p} \partial_i \, \Delta x_{t-1} + \sum_{j=1}^{p} \delta_j \, \Delta y_{t-j} + \mu_{2t}$$

(13)

where $\alpha, \beta, \rho, \partial, \delta$ are coefficients that need to be derived through VAR regression; y_t and x_t represent the variables chosen, and Δy_t and Δx_t are the first differences of these variables that capture their short–run relationships.

The purpose of the causality test that was conducted in this study was to choose the adequate explanatory variable. As such, the causality relationship between just a pair of variables in each case will be analyzed herein.

In equation (12), y_t and x_t represent the real GDP and the EnTco energy total consumption. EnTco causes GDP if the current value of GDP is better predicted by including the past values of EnTco than by not doing so. This means that if EnTco causes GDP, then EnTco helps forecast GDP. Again, from equation (13), GDP causes EnTco if the current value of EnTco is better predicted by including the past values of GDP than by not doing so. This means that GDP helps forecast EnTco (Chontanawat, Hunt, et al., 2008). Specifically, the following null hypotheses are necessarily tested:

- *Null hypothesis (a)*: Ho: $\sum_{j=1}^{p} \rho_j = 0$ (14)

or energy total consumption does not Granger-cause economic growth.

- *Null hypothesis (b)*: Ho: $\sum_{j=1}^{p} \delta_j = 0$ (15)

or economic growth does not Granger-cause total energy consumption.

Chapter 5. Estimation Results and Interpretation

To investigate the relationship that exists among energy consumption, economic growth, copper production, and copper price, this study used the three-stage approach. The order of integration of the variables was sought using the unit root test. Once the order of integration was determined, a test was conducted to determine if there was a cointegrating relationship between each pair of the variables considered at the second step within the vector autoregressive (VAR) model, using the Johansen cointegration test, after determining the optimum number of lags. Finally, whether there was a causal relationship between each pair of variables was determined using the Granger causality test.

5.1 Data scope

Annual time series data were utilized in this study and covered the period 1970-2010 for DRC. The data were obtained from various sources: (1) World Development Indicator (WDI) (2012); (2) International Financial Statistics (2011); (3) Statistical Yearbook published by the United Nations and USGS (2011); and (4) Central Bank of Congo and Ministry of Mines.

The precise definitions of the variables are as follows:

- Gross domestic product (GDP): Real income, defined as GDP in the 2000 constant prices in the local currency “CDF”;
- Energy consumption (Entco): Total energy consumption, which is the sum of hydroelectricity and oil consumption in tons of oil equivalent;
- Copper production (Coprod): Total copper production in metric tons; and

- Copper price (Price): Annual average world copper price in the London Metal Exchange (LME) in US$ (with 1998 as a basic year reported in MP98 and MYB). DRC copper is sold in world markets at prices based on the LME copper price quotation.

Table 5.0: Statistic summary of all annual series

Variable	Obs.	Mean	Std. Dev.	Min	Max
Gdp	41	442011.000	85316.410	290827.100	573744.600
Entco	41	621399.800	98075.050	453302.000	885660.000
Coprod	41	290511.100	202377.000	16359.000	505229.000
Price	41	3409.024	1283.914	1510.000	5690.000

Table 5.1: Variables summary, definitions, and sources

Variable	Definition	Source
GDP	Real income defined as GDP in the 2000 constant prices in the local current million CDF	IMF & Central Bank of Congo (BCC)
Entco	The total energy consumption, which is the sum of hydroelectricity and oil consumption in tons of oil equivalent	WBI & Ministry of Energy (DRC)
Coprod	Total copper production in metric tons	BCC & Ministry of Mines (DRC)
Price	Annual average world copper price in LME in US$ (with 1998 as a basic year reported in MP98 and MYB)	London Metal Exchange (LME)

Figure 5.1 displays DRC's copper production, GDP, and total energy consumption trends spanning 1970-2010.

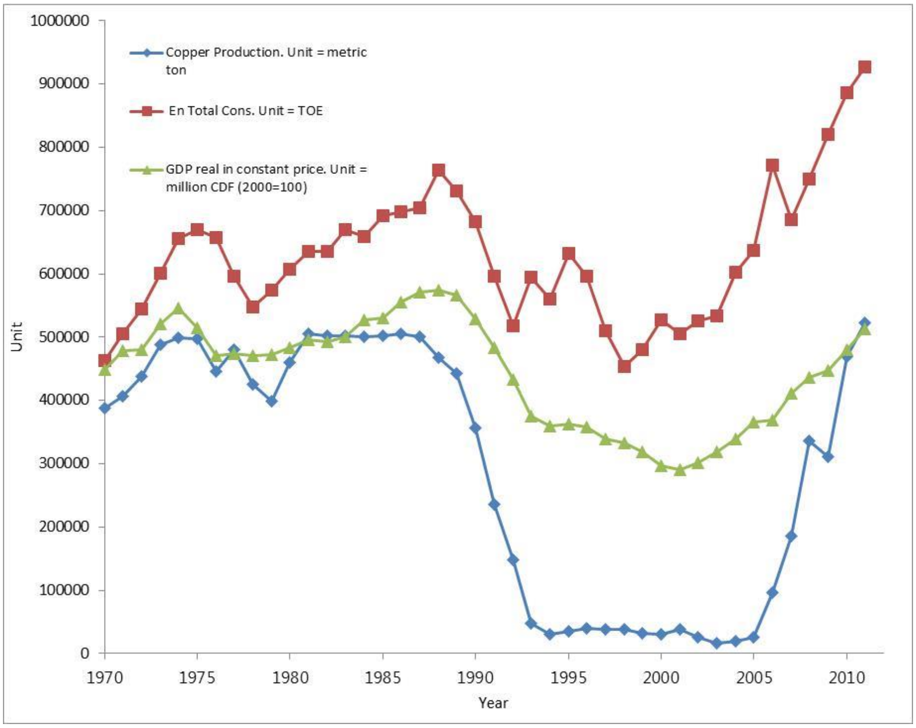

Figure 5.1: DRC's copper production, GDP, and total energy consumption trends.

5.2 Empirical results

5.2.1 Unit root tests

To determine the order of integration of the four variables, the unit root test was achieved via ADF and PP statistics. Both tests were used to check the robustness of the results. Carter et al. (2008) argued that the order of integration is the minimum number of times a variable must be differenced to make it stationary, written as I(d), with *d* being the number of times after differencing. Equations (7) and (8) in Chapter 4 were used to test for unit roots in the series. Table 5.2 shows the results of the ADF and PP tests at the level as well at the first difference for all the four series.

Table 5.2: Unit root test results with ADF and PP

Variables		Level		1st Difference	
		ADF	PP	ADF	PP
GDP	Intercept	-0.843	-1.350	-2.986	-2.999
	Trend & intercept	-0.669	-1.501	-2.964	-2.964
Entco	Intercept	-1.077	-1.444	-5.426	-5.524
	Trend & intercept	-1.164	-1.526	-5.416	-5.404
Coprod	Intercept	-0.689	-1.162	-2.998	-3.073
	Trend & intercept	0.540	-0.618	-3.166	-3.173
Price	Intercept	-1.818	-1.926	-5.457	-5.397
	Trend & intercept	-1.342	-1.431	-5.647	-5.588
1% critical value		-3.648	-3.648	-3.655	-3.655
5% critical value		-2.958	-2.958	-2.961	-2.961
10 % critical value		-2.612	-2.612	-2.613	-2.613

When deciding whether to reject the null hypothesis of a unit root (non-stationary), 5% significance was used for the levels, and 10% for the first differences, with the disparity based on the expectation that the variable would generally be I(0) at the levels and I(1) at the first differences (Chontanawat et al., 2008).

All the four variables (GDP, total energy consumption, copper production, and copper price) were non-stationary in their original level series because their respective test statistics were less than their critical values at 1%, but they were stationary at their first differences at the 5% significance level because their test statistics were greater than the critical value of the model. It appeared that each series was integrated to order 1, which means that it was non-stationary at the level but was stationary at the first difference. This indicates that the variables were individually integrated to order 1 or I(1). Based on the ADF and PP test results, both tests were found to be first-difference-stationary. This situation satisfies Pesaran et al.'s (2001) precondition that the dependent variable must be I(1) and the independent variables I(0) or I(1).

5.2.2 Cointegration test: Johansen's procedure and lag length selection

As it appeared that all the variables were individually integrated to the order 1 or I(1) under investigation, the next step was to determine whether a cointegration between the variables or a long-run relationship exists. If the variables were shown to be cointegrated, the non-standard Granger causality test based on the VECM model was used; otherwise, the first-difference VAR model was used. Before that, the number of lags had to be determined.

5.2.2.1 Lag length selection

For all the variables, the number of lags was determined using the model selection criteria AIC, HQIC, and SBIC, which are automatic settings in the Stata software package, as follows:

- ✧ AIC (Akaike information criterion) estimator;
- ✧ SBC (Schwartz Bayesian criterion) estimator; and
- ✧ HQIC (Hannan and Quinn information criterion) estimator.

The smallest values of AIC, HQIC, and SBIC are the optimum lags, and the result of the cointegration test depends on the number of lags.

Table 5.3: Lag length selection for GDP, Entco, and Coprod

Lag	LR	AIC	HQIC	SBIC
0	NA	25.644	25.659	25.688
1	96.105	23.101	23.131	23.188
2	22.434*	22.548*	22.595*	22.679*
3	0.024	22.602	22.663	22.776
4	2.948	22.576	22.653	22.794

Note: (*) indicates the lag order selected based on the criterion lag=2.
LR: sequential modified LR test statistic (each test at the 5% significance level)

Through these tables, the smallest AIC value, 22.5484, was chosen, which gave optimum lag=2. The lag (2) option was entered into the VAR equations.

5.2.2.2 Johansen cointegration test

The Johansen cointegration test was applied with a lag interval of 2 in the first difference for each pair of series. Two test statistics that estimate the number of cointegrating vectors in Johansen's cointegration procedure were applied to this study. These tests were the trace statistic test and the maximum eigenvalue test (Johansen, 1988).

The trace statistic test attempts to determine the number of cointegrating vectors between the variables by testing the null hypothesis Ho: r=0 against the alternative hypothesis H1: r>0 or r≤1 (r equals the number of cointegrating vectors).

The maximum eigenvalue test tests the null hypothesis that the number of cointegrating vectors is equal to r against the alternative of r+1 cointegrating vectors. If the value of the likelihood ratio is greater than the critical values at a given significance level, the null hypothesis of zero cointegrating vectors is rejected in favor of the alternatives.

Table 5.4: Johansen cointegration test between GDP and Entco

No. of Cointegrations	Eigen-value	Trace Test		Maximum Eigenvalue Test	
		Trace statistic	5% critical value	Max. eigen statistic	5% critical value
Null (r=0)	NA	7.968*	15.41	4.797*	14.07
r≤1	0.11574	3.171	3.76	3.171	3.76

Note: (*) indicates the max. rank selected by criterion.

Table 5.4 shows that the null hypothesis of no cointegration (Ho: r=0) cannot be rejected using both the trace and λ-max test statistics at 5% significance. The calculated values are both less than the critical values. This simply means that there is no long-run relationship between real GDP and electricity consumption for DRC, and maximum rank = 0.

Table 5.5: Johansen cointegration test between GDP and Coprod

No. of Cointegrations	Eigen-value	Trace Test		Maximum Eigenvalue Test	
		Trace statistic	5% critical value	Max. eigen statistic	5% critical value
Null (r=0)	NA	10.977*	15.41	8.726*	14.07
r≤1	0.2004	2.254	3.76	2.254	3.76

Note: (*) indicates the max. rank selected by criterion.

Table 5.5 shows that the null hypothesis of no cointegration (i.e., Ho: r=0) cannot be rejected using both the trace and λ-max test statistics at 5% significance. The calculated values are both less than the critical values. This simply means that there is no long-run relationship between real GDP and copper production for DRC, and maximum rank = 0.

Table 5.6: Johansen cointegration test between Coprod and Entco

No. of Cointegrations	Eigen-value	Trace Test		Maximum Eigenvalue Test	
		Trace statistic	5% critical value	Max. eigen statistic	5% critical value
Null (r=0)	NA	5.719*	15.41	4.476*	14.07
r≤1	0.108	1.243	3.76	2.254	3.76

Note: (*) indicates the max. rank selected by criterion.

Table 5.6 shows that the null hypothesis of no cointegration (Ho: r=0) cannot be rejected using both the trace and λ-max test statistics at 5%. The calculated values are both less than the critical values. This simply means that there is no long-run relationship between copper production and energy consumption for DRC, and maximum rank = 0.

Table 5.7: Johansen cointegration test between Coprod and Price

No. of Cointegrations	Eigen-value	Trace Test		Maximum Eigenvalue Test	
		Trace statistic	5% critical value	Max. eigen statistic	5% critical value
Null (r=0)	NA	8.245*	15.41	6.913*	14.07
r≤1	0.108	1.332	3.76	1.333	3.76

Note: (*) indicates the max. rank selected by criterion.

Table 5.7 shows that the null hypothesis of no cointegration (Ho: r=0) cannot be rejected using both the trace and λ-max test statistics at 5% significance. The calculated values are both less than the critical values. This simply means that there is no long-run relationship between copper production and copper price in the international market.

Table 5.8: Johansen cointegration test among GDP, Coprod, and Entco

No. of Cointegrations	Eigen-value	Trace Test		Maximum Eigenvalue Test	
		Trace statistic	5% critical value	Max. eigen statistic	5% critical value
Null (r=0)	NA	24.031*	29.68	16.608*	20.97
r≦1	0.108	7.423	15.41	4.979	14.07

Note: (*) indicates the max. rank selected by criterion.

Table 5.8 shows that the null hypothesis of no cointegration (Ho: r=0) cannot be rejected using both the trace and λ-max test statistics at 5% significance. The calculated values are both less than the critical values. This simply means that there are no long-run relationships among real GDP, energy consumption, and copper production for DRC, and maximum rank = 0.

It appears that all the series have no cointegration equation, which means that they have no long-run association. Hence, VECM could not be run, and therefore, only the unrestrictible VAR model with first-different series for short run could be run in the sample period for DRC.

5.2.3 Vector autoregressive models (VARs)

Cointegration implies the presence of a long-run relationship between certain economic variables, but such was not the case in this study. As such, the VAR model with first-different series (VAR-D) for short run (defined as one year) was used in this study.

To determine the direction of the causal relationship, which can be unidirectional, bidirectional, and/or no Granger causality (neutrality), the

Granger causality test was also used based on the coefficients of the first-difference values (Δy_t and Δx_t) that capture their short-run relationship. The null hypothesis (Ho) was that there is no causation from Δy_t to Δx_t at 5% significance.

5.2.3.1 VAR estimates of the ΔGDP and ΔEntco models

Table 5.9: VAR estimation results of ΔGDP and ΔEntco

Source of Causality					
Dependent variable	Lag	Coefficient		Prob> |z|	Conclusion on causation
		ΔGDP	ΔEntco		
ΔGDP	1		0.179	0.004*	Yes
	2		0.203	0.742	
ΔEntco	1	1.324		0.002*	Yes
	2	-0.180		0.668	

The results of the VAR-D and Granger causality tests are shown in Table 5.9. As the P-value (0.004) is less than 0.05, the null hypothesis that GDP does not cause energy consumption cannot be rejected. Hence, short-run Granger causality was found from GDP to energy consumption. This is the same as from energy consumption to GDP, where the P-value (0.002) was less than 0.005. Consequently, there is bidirectional causality.

5.2.3.2 VAR estimates of the Δgdp and Δcoprod models

Table 5.10: VAR estimation results of ΔGDP and Δcoprod

Source of Causality					
Dependent variable	Lag	Coefficient		Prob> |z|	Conclusion on causation
		ΔGDP	ΔCoprod		
ΔGDP	1		0.250	0.000*	Yes
	2		0.0521	0.503	
ΔCoprod	1	-0.793		0.100	No
	2	0.491		0.200	

In Table 5.10, short-run Granger causality can be found from GDP to copper production, but not the reverse, at a 5% critical value. This shows the existence of unidirectional Granger causality from GDP to copper production.

5.2.3.3 VAR estimates of the ΔCoprod and ΔEntco models

Table 5.11: VAR estimation results of ΔCoprod and ΔEntco

Source of Causality					
Dependent variable	Lag	Coefficient		Prob> |z|	Conclusion on causation
		ΔCoprod	ΔEntco		
ΔCoprod	1		0.262	0.047	Yes
	2		-0.462	0.001	
ΔEntco	1	0.284		0.178	Non
	2	0.239		0.229	

In Table 5.11, short-run Granger causality can be found from copper production to energy consumption, but not the reverse. As the P-value (0.047) is less than 0.05, the null hypothesis that copper production does not cause energy consumption cannot be rejected. Hence, there is unidirectional causality. The need to increase the copper production in DRC increased the energy demand in the past years, which in turn implies an increase in energy consumption. The current agreements between the Ministry of Energy represented by SNEL (the national electricity company) and mining companies in DRC can be referred to for the projects of upgrading the existing hydro generation plants and/or building new hydroelectric plants. Therefore, the technology of mineral ore extraction and the process of concentrate refining are energy-intensive (Davis, 2009). The result also confirms that an increase in energy consumption will affect mining production expansion.

5.2.3.4 VAR estimates of the Dcoprod and Dprice models

Table 5.12: VAR estimation results of ΔCoprod and ΔPrice

Source of Causality					
Dependent variable	Lag	Coefficient		Prob> |z|	Conclusion on causation
		ΔCoprod	ΔPrice		
ΔCoprod	1		24.170	0.028	Yes
	2		4.529	0.694	
ΔPrice	1	-0.007		0.025	Yes
	2	0.005		0.055	

The results of the VAR-based Granger causality tests are shown in Table 5.12. Short-run causality was found from copper production to copper price, and vice versa. Consequently, there is bidirectional short-run Granger causality. The result is significant at the 5% level.

The feedback hypothesis suggests that there is a bidirectional causal relationship between copper production and copper price in the short run, reflecting the interdependence associated with the mining policies and the national and international environment situations. This suggests the fact that mineral commodity markets are volatile. The major short-run effects of copper price changes are on the output of the copper sector, the investment in the copper and non-copper sectors, and the domestic price level (David & Tilton, 2005).

5.2.4 Granger causality tests

The results of the Granger causality tests between the considered variables are displayed in Table 5.9-10-11 and 5.12. A summary of these results based on the p-value are presented in Table 5-13.

Table 5.13: Summary of the Granger causality tests between time series

Null Hypothesis	P-value	Conclusion
GDP is not the Granger cause of energy consumption.	0.004	Rejected
Energy consumption is not the Granger cause of GDP.	0.002	Rejected
GDP is not the Granger cause of copper production.	0.000	Rejected
Copper production is not the Granger cause of GDP.	0.100	Accepted
Copper production is not the Granger cause of energy consumption.	0.047	Rejected
Energy consumption is not the Granger cause of copper production.	0.178	Accepted
Copper production is not the Granger cause of price.	0.028	Rejected
Price is not the Granger cause of copper production.	0.025	Rejected

5.3 Empirical results interpretation

Bidirectional Granger causality running from economic growth to energy consumption:

The existence of bidirectional Granger causality running from energy consumption to economic growth, and vice versa, can be explained from the perspectives of economic structure and energy usage structure. DRC has been experimenting on a positive GDP growth rate since 2002, and it has since been constantly increasing. The positive bidirectional causality (feedback) implies that economic growth demands more energy use and that higher energy consumption induces economic growth. In DRC, electricity consumption infrastructure shortages and the problems of blackout and constant power interruptions can jeopardize the social and economic progress. To increase the supply of electricity, adequate investment provisions should be made by involving private capital, which is conspicuously lacking. By investing more and reducing the inefficiency in the supply and use of electricity, the energy sector can stimulate economic growth. DRC has the lowest level of energy efficiency in Africa (ECA, 2010). Generating an adequate electricity supply for sustainable development is crucial for the country, where the electrification rate is only 11%.

Unidirectional Granger from the growth of GDP to copper production:

DRC's mineral sector has rebounded significantly since 2002, and it is currently the main foreign exchange earner, with the percentage of the mining output in the GDP increasing from 2% in 2001 to 15.5% in 2011.[5]

On the other hand, the percentage of GDP growth is positive and has been increasing since 2002. This ratio of the mining sector output in the GDP means that an increase in energy consumption will lead to GDP growth by increasing the mining output. Energy supply shortage, on the other hand, will negatively influence the growth of the mining industry output and will restrain the growth of the aggregate output.

The existence of unidirectional Granger causality from GDP growth to the growth in mining output can be said to be a consequence of the previous situation. It can be seen in Figure 5.1 that the sharp increases in copper production started in 2005. The figure also shows the same trend as with energy consumption. This explains why copper production is the Granger cause of energy consumption. It can be concluded that an increase in energy consumption is influenced not only by GDP growth but also by copper production.

<u>Unidirectional Granger causality from copper production to energy consumption</u>:

The existence of unidirectional Granger causality from copper production to energy consumption can be explained by the recent increase in the energy demand from the mining companies. In the context of the public-private partnership (PPP) between the state-owned company SNEL and mining companies, several agreements for some projects have been concluded

[5]Central Bank of Congo Annual Report 2011

to date, with the objective of increasing the power generation to allow the mining operators to meet their energy demand for their mining activities. The private partner provides funds for the project, and repayment of such fund is guaranteed and secured from a portion of the revenues from the electricity utility bills or by the customer himself and/or by another customer targeted on agreed-upon terms, through pledge agreements.

These projects include that involving the rehabilitation and/or upgrading of the existing equipment and facilities, network reinforcement, and building new hydroelectric plants.

Bidirectional Granger causality running from copper production to copper price:

Bidirectional Granger causality was found running from copper production to copper price, and vice versa. Why does bilateral causality exist between copper production and copper price in the short run? It is comprehensible that economic fluctuation leads to fluctuation in copper production and consumption, but it is also true that copper shortage or copper production fluctuation from a big producer and/or consumer may lead to fluctuation in the total output and therefore a fluctuation in the price in the international market.

Chapter 6. Conclusion and Policy Implications

6.1 Summary

This study intends to investigate the long-run relationships among some determinants, such as economic growth, as measured by gross domestic product (GDP), energy consumption, copper production, and copper price in the international market, for the Democratic Republic of the Congo (DRC). Annual time series were utilized and spanned 1970-2010. A cointegration approach was used to evaluate the direction of causality among them. Based on the results of the investigation of the long-run relationships among these variables, it can be concluded that such variables have no long-run relationships but that there exist short-run relationships among them.

6.2 Key findings and policy implications

In the analysis of the causality effect, a strong evidence of bidirectional causality between economic growth and energy consumption was found, which is in conformity with the results of some previous studies (Asafu-Adjaye, 2000; Wolde-Ruffael, 2006). Unidirectional causality was also found from GDP growth to copper production. Again, unidirectional causality was found from copper production to energy consumption. This can be explained by the fact that copper extraction and processing are energy-intensive. Finally, bidirectional causality was found between copper production and copper price in the international market. This also confirms the fact that mineral commodity markets are volatile (Davis & Tilton, 2005).

The empirical analysis of economic growth and energy consumption has important policy implications on DRC's economic policy. From the policy perspective, the confirmation of the feedback hypothesis warns against the use of policy instruments geared towards restricting energy consumption as they may lead to adverse effects on economic growth. As DRC's electrification rate is only 11%, it may not be feasible to reduce the country's energy consumption. What is needed is to make the electricity sector more efficient so as to produce a greater output per unit of electricity used. Therefore, conservation measures to increase the efficiency per unit of output are not pressing in DRC. Emphasis should be placed mainly on supply-side options and energy efficiency than on energy-limiting policies.

Given DRC's extensive dependence on petroleum product imports for its national needs, any supply shock will negatively affect its development. To enhance its supply security, DRC's energy policies should focus on reducing the country's dependence on external energy sources. The government should thus prioritize the development of domestic energy sources, such as expanding its hydroelectric-power production, promoting the use of wind/ solar/geothermal energy and other types of energy, and pushing forward its on- and off-shore exploration of petroleum and natural gas, given its energy potential, as shown in Table 2.6.

DRC's government is currently carrying out sector electricity and hydrocarbon reform. It should speed up the adoption and promulgation of the new energy code, a bill currently going through the parliamentary process. This piece of legislation will provide a strong incentive for private investment due to the enlargement of the institutional framework, which will include an electricity regulatory authority. In the meantime, the already-underway restructuring process of the national electricity and oil companies to make them independent commercial entities that can adequately invest in their growth and provide dividends to the government should be made effective. Performance-based economic incentives may be desirable to encourage private investment influx.

The major short-run effects of copper price changes are on the copper sector output, the investment in the copper and non-copper sectors, and the domestic price level. Fiscal policy can be used to offset the decline in economic activity when the copper price falls, but this will depend on the availability of domestic and foreign financial reserves. A policy of output maximization in the copper industry can be used to reduce the real instability engendered by copper price volatility.

In terms of policy, the mining sector in DRC experienced positive and strong growth in the last decade, and the rapid expansion of production (by more than 1615% from 2001 to 2010) is due to the massive private-capital inflows through public-private partnership (PPP), but the management of the partnership is not proactive in proposing modalities for better development, for several reasons. To address this situation, the government policies should focus on strengthening institutions through capacity building, and on effectively and efficiently supervising, monitoring, and ensuring transparency and accountability in the mining sector.

DRC’s economy is very dependent on mineral resources, according to several measures (IMF, 2010). Considering the exhaustive nature of mineral resources, the government policy should focus on re-investing a significant proportion of its mineral rent to develop the non-mineral sectors for greater economic growth and sustainable development ventures for the future generation.

DRC’s massive investment in the copper sector in recent years, and the ongoing projects on track, in addition to the large proven and economically exploitable reserves of copper and cobalt, indicate that copper will remain very important in DRC’s economy in the future.

In the long run, however, for DRC's development to be sustainable, DRC has to change its economic structure into one characterized by more efficiency-oriented resource exploitation and use because the country has untapped and diversified natural resources.

Recommendations for further study

The future researches examining DRC using a regional panel framework may provide additional insights regarding the impact of oil resource import on the relationship between energy consumption and GDP.

Analysis of the Long-Run Relationship between Copper Production and the World Copper Market

- With Focus on the Determinants of Copper Market Share Increase from Upstream-producing Countries -

Chapter 7. Introduction

The global consumption of key minerals increased sharply in the last two decades. The sustainable supply of minerals is a global problem, and metal production has increased rapidly with the global economic growth (Figure 1) (Nishiyama, 1996). The increase in economic prosperity and well-being of nations and individuals has propelled a quest for technological advancement that leverages on the availability of mineral resources. From the demand side, copper is playing the strategic role of supporting the world's technological and manufacturing development.

Copper is a traditional metal with a long history, and a commodity that measures the pulse of the global economy. From the supply-side perspective, copper production plays a significant role in supporting the economic development of many mineral-rich, mostly developing countries, which provide most of the world's copper needs.

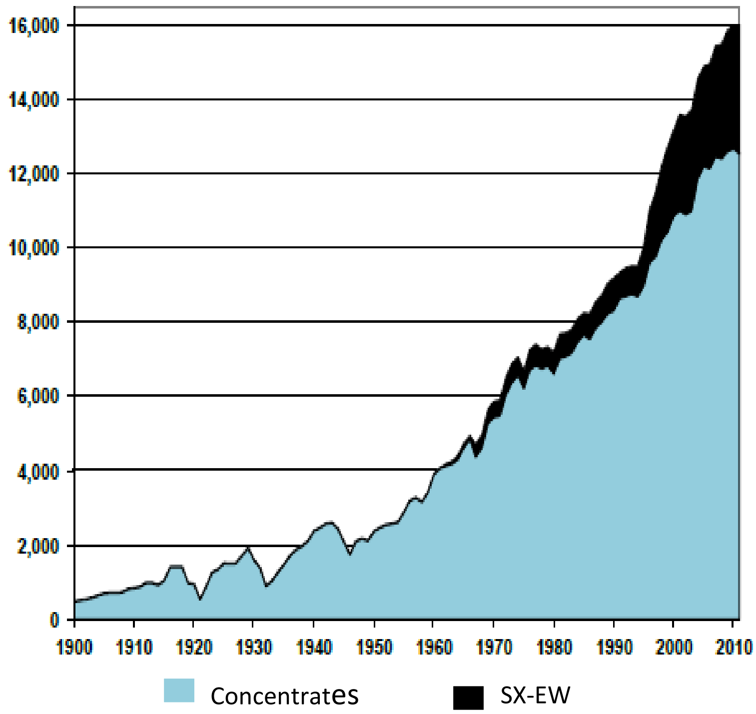

Figure 7.1: World copper mine production, 1900-2011 (thousand metric tons).

Source: ICSG

7.1 Motivations and objectives of this study

This study was motivated by DRC's interest in understanding the behavior of the world copper market so as to assist its government in planning, as copper is the predominant export product of DRC and as the copper mining industry contributes significantly to the country's GDP and government revenues in terms of foreign currencies for its exports. It is imperative to investigate the drivers of economic behavior in the mining sector in DRC and internationally to reposition the industry for efficient and sustainable copper production and economic growth. Despite the growing strand of empirical literature in mineral resources, there is a dearth of empirical studies investigating the drivers of market share increase of the copper commodity from the supply-side perspective.

This study was conducted to bridge such gap, to investigate the drivers of market share increase of each country‘s copper production in the international copper market, to explain some factors that influence the production side, to unravel implications that can guide policymaking, and to contribute to the empirical literature on the economics of natural resources.

The research question

As DRC’s copper industry forms a great part of the country’s national economy, what should DRC do to increase its international copper market share?

7.2 Study outline

This study outline presents an overall view of the content of this work. The current chapter (Chapter 7) gives a brief introduction of the work and presents its motivations and objectives. Chapter 8 presents an overview of the copper commodity and the global market, highlighting the world’s copper reserves, the constraints on the copper supply, the major users of copper, and the trade and exchanges of copper. The existing literature analyzing the current state of knowledge in the mineral field is presented in Chapter 9. Chapter 10 presents and discusses the study method that was used in this work, reveals the data obtained, explains the variables used, and defines the hypotheses. Chapter 11 presents the empirical results obtained and the results of their analysis. Finally, the study’s conclusion and policy implications are discussed in Chapter 12. These findings will be used to give suggestions or recommendations to the policymakers for the more effective management of DRC's mining sector, and to suggest policies for copper-producing countries.

Chapter 8. Copper and the Global Copper Market

Copper products across the value chain are traded internationally. Often, countries whose upstream copper production capacity exceeds their downstream production capacity will import the raw materials needed to meet their production needs, and vice versa. The major product categories of copper traded internationally include copper concentrates, copper blister and anode, copper cathode and ingots, copper scrap, and copper semis. The changes in trade regulations, such as the imposition of import duties or export quotas, can have a significant impact on the international trade of copper (The World Copper Factbook, 2012).

8.1 Copper reserves and constraints on the copper supply

On the supply side, according to the U.S. Geological Survey, Mineral Commodity Summaries, 2012 (Table 6.1), the least developed countries (LDCs) and other countries account for 60.7% of the world‘s annual production and around two-thirds of the world’s known copper reserves. Hence, they will continue to play a strategic role in the global copper supply market. With copper concentrate in strong demand, there has been a growing interest in understanding the obstacles that can prevent the copper mine supply from coming on-stream. The following are some of the operational and financial constraints that were identified (ICSG, 2009):

- falling grades: a serious issue in developed copper areas such as USA and Chile;

- project finance: the cost of capital is a central factor, and high interest rates may significantly reduce the supply;
- tax and investment regimes: the recent research indicates that these are less important than geological endowments;
- water supply: a critical issue in dry mining areas;
- energy: coal is the fuel chosen to power main copper mines and processes, and climate change may increase the costs;
- skilled labor: open labor markets will help address this constraint;
- market power concentration: the risk has moved to the import demand side in recent years; and
- peace and security.

Table 8.1: Proven reserves distribution for country groups (2011)

Country Group	**Reserves (%)***	**Production (%)***
OECD	15.1	19.3
BRICS	8.7	15.2
LDCs & other countries	64.6	60.7
The rest	11.6	4.8
World	100	100

*NB: Computed from U.S. Geological Survey, Mineral Commodity Summaries, 2012.

8.2 Major uses and end users of copper

The global demand for copper continues to grow. The world's refined usage has more than tripled in the last 50 years due to the expanding sectors (e.g., electrical/electronics/communications products, building construction, industrial machinery and equipment, transportation equipment, consumer and general products) and the usage by end use sector (Figure 6.2).

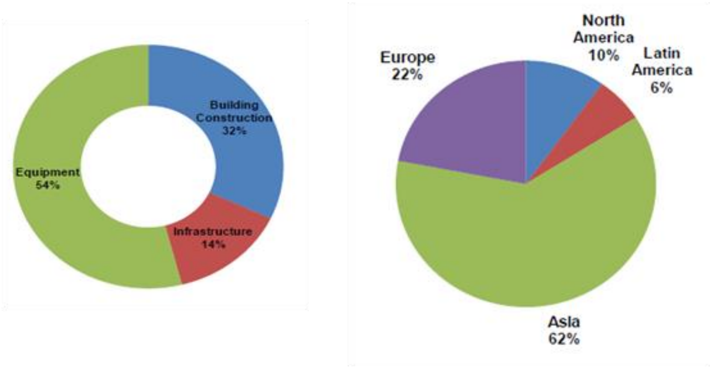

Figure 8.1: Major usage of copper by region and end use sector, 2012**.**
Source: ISCG, The World Copper Factbook, 2012.

8.3 Trade and exchanges of copper

Copper is traded between producers and consumers. Producers sell their present or future production to clients, who transform the metal into shapes and/or alloys to allow downstream fabricators to transform these into different end-use products. The most important factor in the copper trading process is the price settlement for the present day (spot price) or for the future days.

The main role of commodity exchange is to facilitate the process of settling prices, and to make it transparent. Three commodity exchanges provide the facilities for copper trading: London Metal Exchange (LME), the Commodity Exchange Division of New York Mercantile Exchange (COMEX/NYMEX), and Shanghai Metal Exchange (SHME). In these exchanges, the prices are settled by bid and offer, reflecting the market's perception of the supply and demand of a commodity on a particular day.

Exchanges also provide for the trading of futures and options contracts. These allow producers and consumers to fix a price in the future, thus providing a hedge against price variations. The existence of futures contracts allows producers and their clients to agree on different price settling schemes to accommodate their different interests. Futures contracts have gradually changed over the years to correspond to the most active markets. At the end of 1989, COMEX dropped the standard contract and adopted a high-grade contract. LME dropped its standard cathode contract in January 1989 and currently trades only the grade A (high-grade) cathode contract (ISCG, 2013).

Chapiter 9. Literature review

It is widely assumed that countries that possess rich mineral deposits are fortunate. Such deposits are assets, part of a country's capital. Mining is a key that converts dormant mineral wealth into schools, homes, ports, and other forms of capital that directly contribute to economic development. Over the past two decade, however, a more negative view of mining has emerged that questions the positive relationship between mineral extraction and economic development following some empirical studies suggesting that countries where mining is important have not grown as rapidly as other countries .

More recent studies have explored the possible reasons behind the disappointing performance of many mineral producing countries. While the central point of contention between the conventional and the alternative views namely," whether or not mining usually promotes economic development remains unresolved, there is widespread agreement that rich mineral deposits provide developing countries with opportunities, which in some instances have been used wisely to promote development, and in other instances have been misused, hurting development. The consensus on this issue is important, for it means that one uniform policy toward all mining in the developing world is not desirable, despite the recent suggestions by some to the contrary. (Davis & Tilton, 2005)

The mining policy systems differ among the countries according to their characteristics, which include natural resources endowments, political and economic systems, social and cultural traditions. These differences affect policy choices among countries and make some policies applicable and /or not in certain countries. That is what can lead to differences in mining policies applications.

Government policies have a crucial role in mining development. Different countries have set up different policy tools according to their mineral policy but the effectiveness of these policy tools and implementation capacity is negotiable. Many resource-based economies have performed poorly, not because they overemphasized minerals, but because they have failed to develop their mineral potential through appropriate policies (Wright and Czellusta, 2003).

Mehlum et al. (2006) studied formally an economy where skilled entrepreneurs can choose between rent-seeking and productive activities such as starting a firm. They show that when resources rents are high and institutional quality low, the outcome is that a number of entrepreneurs choose to be rent-seekers. In this situation an increase in natural resources rents will result in more entrepreneurs becoming rent-seekers. This rent-seeking perspective thus suggests that countries have bad institutions. Therefore institutions in this setting are institutions governing the private sector, such as the rule of law, which influence the relative profitability of productive activities. Davis (2005) confirms this by arguing that, as always, good governance requires adequate incentives, either by extensive property rights and a domestic political structure that constrains inappropriate public sector behavior.

Furthermore, a large empirical literature has documented the huge differences institutions across countries, and has shown that these can explain a large part of cross-country differences in output per capita. Among the empirical studies that have been done in the last years about the influence of institutions on growth and development, there are the one of Mauro (1995), Acemoglu et al. (2001, 2002), Easterly and Levine (2003), and Mehlum et al. (2006). All of them find a positive relation between good institutions and development.

However in the empirical literature the term institutions encompass a wide range of indicators, including: institutional quality (the enforcement of property rights) ; political stability (riots, coups, civil wars); distinctiveness of political regimes (elections, constitutions, executive powers); social characteristics (differences in income and historical background), etc. Economists often rely on one or several of these types of indicators to capture the feature of institutions, although each one has a potentially different channel of impact on growth (Pessoa, 2008).

David and Wright (1997) argued that the abundance of mineral resources should not be seen as merely a fortunate natural endowment, but is more appropriately understood as a form of collective learning, a return on large-scale investments in exploration, transportation, geological knowledge, and the technologies of mineral extraction, refining, and utilization.

Mineral constitute a high-tech knowledge industry in many countries. Nonrenewable resources have been progressively extended through geological knowledge and exploration, technology progress and the technologies of mineral extraction, refining, and utilization.

Brunnschweeiler (2008) applied ordinary least square regression and two-stage least square regression models in a cross-country analysis of natural resource abundance, institutions and economic growth for the period 1994-2000. The empirical results point a significant positive effect of natural resource abundance, especially for mineral resources when considering institutional quality and its possible interaction.

Pessoa (2008) applied a regression in a panel data analysis of 119 countries for the period of 1980-2004 when investigating natural resources and institutions. He found positive association between growth rate and rate of change in institutions when controlling the natural resources export.

Chapter 10. Methodology and Data

The following are the model framework and the estimation procedure, variables, and data sources.

10.1 General form of the theoretical model

The main objective of this study was to investigate the drivers of market share increase of each country's copper production in the international copper market.

The basic model will estimate the effects of different determinants (factors) on a country's copper production share. These determinants can vary among countries depending on such countries' characteristics, such as those relating to geopolitical, socioeconomic, and country-specific factors.

The analysis stage will include the following:

(1) calculation of the correlation matrix between the variables;

(2) panel data estimation using the fixed- and random-effects models;

(3) Hausman test to check the fixed or random effects for better results prediction; and

(4) heteroskedasticity and/or autocorrelation tests.

The model assumption is that the market share of each country's copper production is a function of governance, socioeconomic, and country-specific factors.

Market share = f (governance, socioeconomic, and country-specific factors)

The cross-country panel data approach was applied to this analysis. The general panel data model takes the following form:

$$Share_{it} = \alpha + \beta_1 G_{it} + \beta_2 S_{it} + \varepsilon_{it} \qquad (0)$$

where i is an individual country, t is the year, $Share_{it}$ is the market share of each country's copper production, G_{it} is the vector of governance factors, S_{it} is the vector of socioeconomic factors, and ε_{it} is the error term.

The coefficients were estimated using the fixed- and random-effects models, to determine the unobserved time-invariant country-specific differences. This modeling approach has several advantages, as listed by Baltagi (1998). First, as panel data relate to individuals, firms, states, countries, etc., over time, there is bound to be heterogeneity in these units. These techniques of panel data estimation can explicitly take such heterogeneity into account by allowing for subject-specific variables. Second, panel data are more informative and have greater variability, less collinearity among the variables, a higher degree of freedom, and greater accuracy by combining the time series of the cross-section observations. Third, panel data are better suited for determining the dynamics of change when studying the repeated cross-section of observations, and can also detect and measure the effects that simply cannot be observed in pure cross-section or pure time series data.

10.1.1 Fixed- and random-effects model specifications

The assumption of the fixed-effects model is that the individual specific effects are correlated with the explanatory variables. The random-effects model assumes, on the other hand, that the individual specific effects are correlated with the explanatory variables (Woodridge, 2009; Baltagi & Chang, 1994).

Consider the following formula:

$$y_{it} = \alpha + \beta_1 X_{it} + \mu_i + \varepsilon_{it} \qquad (1)$$

i= 1…….21, and t= 1……20,

where y_{it} is the dependent variable, X_{it} is the independent variable, μ_i is the unobserved country's time-invariant effect, and ε_{it} is the error term. Unlike the random-effects model, where the unobserved μ_i is independent of X_{it}, the fixed-effects model allows μ_i to be correlated with regressor matrix X_{it}.

If equation (1) is true, it must also be true that

$$\bar{y}_i = \alpha + \beta_1 \bar{X}_i + \mu_i + \bar{\varepsilon}_i \qquad (2)$$

where $\bar{y}_i = \frac{1}{T}\sum_{t=1}^{T} y_{it}$, $\bar{X}_i = \frac{1}{T}\sum_{t=1}^{T} X_{it}$, $\bar{\varepsilon}_i = \frac{1}{T}\sum_{t=1}^{T} \varepsilon_{it}$

while y_i, X_i changes over time due to the country differences but μ_i does not change.

Based on the difference between equations (2) and (1), it must also be true that

$$y_{it} - \bar{y}_i = \beta_1 (X_{it} - \bar{X}_i) + (\varepsilon_{it} - \bar{\mu}_i) \qquad (3)$$

The three equations above form the basis for estimating the fixed-effects model. In the Stata software, the command (xtreg, fe) performs the estimation of the fixed effects within the estimator.

The random-effects model assumes that there is a correlation between the country-specific time-invariant heterogeneity and the explanatory variables.

$$Cov(X_{it}, \mu_{it}) = 0$$

$$y_{it} = \alpha + \beta_1 X_{it} + \mu_i + \varepsilon_{it} \tag{4}$$

but there is a two-component error term,

$$\vartheta_{it} = \mu_i + \varepsilon_{it}.$$

To eliminate the serial correlation, equation (4) was transformed into

$$\widetilde{y_i} = \alpha + \beta_1 \tilde{X}_{it} + \widetilde{\vartheta_i} \tag{5}$$

γ was introduced in equation (5), defined in terms of $\mu_i + \varepsilon_{it}$, and taking the difference between equations (4) and (5), the random-effects estimator turned out to be equivalent to the following estimation:

$$y_{it} - \gamma\widetilde{y_i} = (1 - \gamma)\alpha + \left(X_i - \gamma\widetilde{X_i}\right)\beta_1 + \left[(1 - \gamma)\vartheta_i + (\vartheta_{it} - \gamma\ \widetilde{\vartheta_i}\ )\right] \tag{6}$$

where γ is a function of $\theta_\mu^2 + \theta_\varepsilon^2$. The random-effects estimator uses both the within and between information. Considering the variation in equation (1), this yields

$$y_{it} = \alpha + \beta_1 \bar{X}_i + (X_{it} - \bar{X}_i)\beta_2 + \mu_i + \varepsilon_{it} \tag{7}$$

Similarly, considering the variations in equations (2) and (3),

$$\bar{y}_i = \alpha + \beta_1 \bar{X}_i + \mu_i + \bar{\varepsilon}_i \tag{8}$$

$$y_{it} - \bar{y}_i = \beta_2 (X_{it} - \bar{X}_i) + (\varepsilon_{it} - \bar{\mu}_i) \tag{9}$$

That is, the between estimator estimates β_1, and the within estimator estimates β_2. The quality of the fit can be assessed with respect to equations (1), (2), and (3), given the $\widehat{\alpha}$ and $\widehat{\beta}$ estimates of α and β:

$$\hat{y}_{it} = \hat{\alpha} + X_{it}\hat{\beta} \tag{10}$$

$$\hat{\bar{y}}_i = \hat{\alpha} + \bar{X}_i\hat{\beta} \tag{11}$$

$$\hat{\hat{y}}_{it} = (\hat{y}_{it} - \hat{\bar{y}}_i) = (X_{it} - \bar{X}_i)\hat{\beta} \tag{12}$$

To estimate the random-effects model using the Stata software, the command (xtreg, RE) was used.

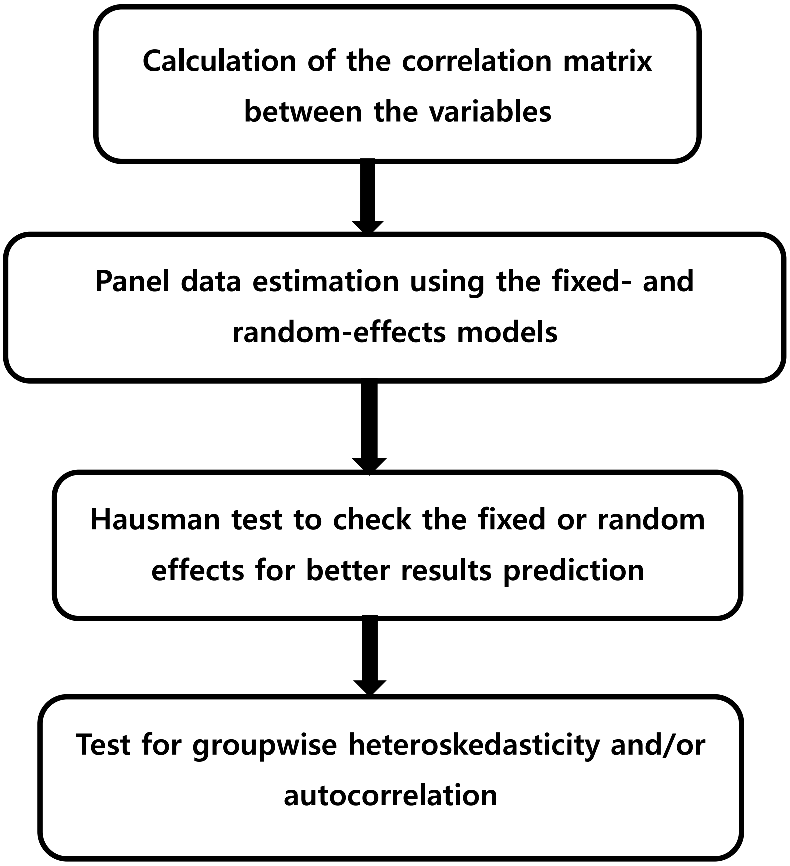

Figure 10.1: Flow of analysis**.**

Before starting the analysis, some assumptions are listed below:

- The copper mining industry in a single country is assumed to be a price taker. Thus, the world price of copper is exogenous to the model. No country on its own can influence the copper price for any extent of time by altering its output. In the case of the copper producers selling at the producers' price, it is assumed that this price is set independently of the supply decision, but the average price is still dictated by LME.

- The copper production in a single country is postulated in the short run to be affected by the relation between the copper price and the cost of production. For copper production, it is assumed that output decisions are based on profit maximization, and in each period, full capacity is produced, implying output maximization.
- The copper demand will still increase in the near future due to the world's population growth, the advances in technology, and the rising standard of living (Nishiyama, 1996).

10.2 Data and variable descriptions

The panel data analysis that was conducted in this study spanned the years 1991-2010 and involved 21 copper-producing countries accounting for over than 96% of the world's copper mine production. This period was chosen due to data availability and because the period corresponds to the time when the two-price system in the copper market was abandoned and the one-price regime was adopted in the free-market LME.

In this study, the drivers of market share increase of each country's copper production in the international copper market were investigated in four groups of countries. The first group included all countries, the second group the OECD countries, the third group the BRICS (Brazil, Russia, India, China, and South Africa) countries, and the last group the least developed countries (LDCs) and other countries (Table 6.2). The analysis was conducted for all countries' copper producers as a whole and then for each group within the copper industry.

Table 10.1: Country groups in the current study

WORLD COUNTRY COPPER PRODUCERS		
OECD	BRICS	LDCs & others
Australia, Canada, Finland, Poland, Portugal, USA	Brazil, Russia, India, China, South Africa	Bulgaria, Chile, Iran, **DRC**, Indonesia, Kazakhstan, Mexico, Peru, Philippines, Zambia

The data used are obtained from different sources. The copper price is from LME, the data on copper productions are from the International Copper Study Group, Copper Development Association Inc., and the other data including the governance and socioeconomic factors were obtained from the World Bank database.

Variables

Many scholars have used several policies, socioeconomic, institutional, political, and technical variables to investigate the drivers of growth in the mining industry. In this study, geopolitical and socioeconomic factors were focused on to investigate the relationship between the explanatory variables chosen and the increase in mining output as the dependent variable.

The dependent variable is the market share of a country's copper production in the world copper mine production.

The explanatory variables were chosen according to the literature. They were classified into two categories, as follows:

(1) Governance and country-specific factors:

Governance consists of the traditions and institutions by which authority in a country is exercised. These include the process by which governments are selected, monitored, and replaced; the capacity of the government to effectively formulate and implement sound policies; and the citizens' and state's respect for the institutions that govern the economic and social interactions among them.

Governance also includes the geopolitical situation of the country, such as the political stability and the government effectiveness; the government policy factors such as the regulatory quality, and the country-specific factors such as the number of researchers in R&D per million people and the strength of the investor protection index.

The government effectiveness captures the perceptions of the quality of public services, the quality of the civil service, the degree of its independence from political pressure, the quality of the political formulation and implementation, and the credibility of the government's commitment to such policies.

Institutional and regulatory quality captures the perceptions of the ability of the government to formulate and implement sound policies and regulations and institutions that permit and promote private-sector development.

(2) Socioeconomic factors: GDP per capita, energy consumption per capita, energy import, mineral rents, foreign-direct-investment flow, industry value added, research and development expenditures, etc.

Table 10.2: Variables summary, definitions, and sources

Variable	Definition	Source
Share	Country's copper production share in the total world production (annual %)	ICSG & CDA
gdp	GDP per capita (current US$)	WB
epc	Energy consumption (Kg of oil equivalent per capita)	WB
eimp	Energy imports, net (% of energy use) oil equivalent	WB
ps	Political stability and government effectiveness (percentile rank)	WB
rq	Institutional and regulatory quality (percentile rank)	WB
mr	Mineral rents (% of GDP)	WB
fdi	Foreign direct investment, net inflows (% of GDP)	WB
Iva	Industry value added (% of GDP)	WB
rdexp	Research and development expenditures (% of GDP)	WB
resrd	Researchers in R&D (per million people)	WB
si	Strength of investor protection index (0 to 10)	WB

The summary statistics of variables in Table 6.4 show a significant change over time, as evidenced by their standard errors. This is indicative of within-subject variability.

Table 10.3: Summary statistics of variables

Variable	Obs.	Mean	Std. Dev.	Min	Max
share	420	4.949	7.467	0.121	40.880
gdp	420	8783.746	11935.470	86.750	51628.600
epc	420	2652.925	2360.397	293.67	8424.040
ps	420	45.209	29.117	0.962	100.000
rq	420	59.271	27.516	0.490	99.510
mr	420	1.865	3.700	0	24.332
fdi	420	4.235	6.614	0.003	43.761
iva	420	31.416	9.522	0.884	51.006
rdexp	420	0.844	0.844	0.006	3.934
resrd	420	1436.409	1820.520	43.297	8007.531
si	420	5.652	1.431	3.000	8.700

10.3 Hypotheses

Two hypotheses are assumed: that each of the independent variables substantially influences copper production, and thus, the country copper market share in the international market.

Hypothesis 1: Governance has a crucial role in the mineral development of a country. Governance consists of the traditions and institutions by which authority in a country is exercised. This includes the process by which governments are selected, monitored and replaced; the capacity of the government to effectively formulate and implement sound policies; this includes the following determinants: political stability and absence of violence; regulatory quality, etc. (WBI, 2013). Many resource-based economies have performed poorly not because they overemphasized minerals but because of bad governance.

Hypothesis 2: Socioeconomic and country-specific factors are significant in copper production. Each copper-producing country should realize its potentials as well as advantages so as to implement relevant policies based on these advantages.

A domestic endowment of mineral resources is necessary but not sufficient for the production and export of minerals, a supportive legislative framework, and adequate natural or man-made infrastructure such as roads and ports, are all important to turn the resource stock into production and exports (Tilton, 1992).

There is a relation between mineral production and some mineral development factors, such as an accommodating legal environment for private-sector investment (because the mining industry is capital-intensive) as well as investment in the infrastructure of public knowledge and mining-related education.

Chapter 11. Empirical Results and Analysis

11.1 Results

In this study, the drivers for increasing the market share of each country's copper production in the international copper market were investigated. A panel consisting of 21 countries was analyzed, including the OECD, the BRICS, and LDCs and other countries, over the period of 1991-2010. The coefficients of the model were estimated using the fixed- and random-effects models. The Hausman test was applied to select the best fit between the two models model. For all the country groups in the current study, the fixed-effects model was confirmed by the Hausman test. The empirical results for the all-countries group and for the LDCs & others group, where DRC belongs, are given in Table 11.1 and 2 and in Table 11.3 and 4, respectively. The summary of the fixed-effects model's results as confirmed by the Hausman test are presented in Table 11.5. Appendix 2 consists of the tables showing the empirical results for all the country groups in the current study.

Table 11.1: All countries' copper market share fixed-effects model

Fixed-effects (within) regression		No. of obs =	420
Group variable: id_number		No. of groups =	21
R-sq: within	= 0.1700	Obs per group: min =	20
between	= 0.0583	avg =	20.0
overall	= 0.0669	max =	20
		F(10,389) =	7.97
corr(u_i, Xb)	= -0.1509	Prob>F =	0.00

lnshare	Coef.	Std. Err.	t	P>l t l	95% Conf.	Interval
lnepc	0.5176	0.1798	2.8800	0.0040	0.1641	0.8712
eimp	0.0002	0.0014	0.1400	0.8870	-0.0026	0.0030
lnps	0.3293	0.0739	4.4500	0.0000	0.1840	0.4746
lnrq	-0.2085	0.1012	-2.0600	0.0400	-0.4073	-0.0098
mr	0.0494	0.0105	4.7000	0.0000	0.0288	0.0701
fdi	-0.0132	0.0082	-1.6200	0.1050	-0.0293	0.0028
lniva	0.1691	0.1519	1.1100	0.2660	-0.1296	0.4678
lnrdexp	-0.1143	0.0696	-1.6400	0.1010	-0.2511	0.0225
lnresrd	-0.3173	0.1099	-2.8900	0.0040	-0.5334	-0.1011
lnsi	-0.7288	0.4020	-1.8100	0.0710	-1.5191	0.0615
_cons	-0.8010	1.4109	-0.5700	0.571 0	-3.5750	1.9729
sigma_u	1.2183					
sigma_e	0.3770					
rho	0.9126	(fraction of variance due to u_i)				

F-test that all u_i=0: F(20,389)=96.59 Prob>F=0.0000

Table 11.2: All countries' copper market share random-effects model

Random-effects GLS regression					No. of obs =	420
Group variable: id_number					No. of groups =	21
R-sq: within	= 0.1654				Obs per group: min =	20
between	= 0.2008				avg =	20.0
overall	= 0.1971				max =	20
					Wald chi2(10) =	82.42
corr(u_i, X)	= 0 (assumed)				Prob>chi2 =	0.0000
lnshare	Coef.	Std. Err.	Z	P>l Z l	95% Conf.	Interval
lnepc	0.6120	0.1561	3.92	0.000	0.3061	0.9179
eimp	-0.0006	0.0013	-0.42	0.676	-0.0031	0.0020
lnps	0.3285	0.0720	4.56	0.000	0.1874	0.4695
lnrq	-0.1441	0.0979	-1.47	0.141	-0.3360	0.0478
mr	0.0493	0.0102	4.83	0.000	0.0293	0.0692
fdi	-0.0157	0.0080	-1.96	0.050	-0.0314	-0.00002
lniva	0.1753	0.1387	1.26	0.206	-0.0965	0.4470
lnrdexp	-0.1244	0.0675	-1.84	0.065	-0.2567	0.0078
lnresrd	-0.2504	0.1023	-2.45	0.014	-0.4509	-0.0500
lnsi	-0.4970	0.3703	-1.34	0.180	-1.2227	0.2287
_cons	-2.5896	1.1419	-2.27	0.023	-4.8277	-0.3515
sigma_u	0.9351					
sigma_e	0.3770					
rho	0.8602	(fraction of variance due to u_i)				

Table 11.3: LDCs & other countries' copper market share fixed-effects model

Fixed-effects (within) regression					No. of obs =	200
Group variable: id_LDCs					No. of groups =	10
R-sq: within = 0.2578					Obs per group: min =	20
between = 0.0229					avg =	20.0
overall = 0.0370					max =	20
					F(10,180) =	6.25
corr(u_i, Xb) = -0.2854					Prob>F =	0.00

lnshare	Coef.	Std. Err.	t	P>l t l	95% Conf.	Interval
lnepc	0.4432	0.2845	1.56	0.121	-0.1182	1.0045
eimp	0.0031	0.0021	1.48	0.140	-0.0010	0.0073
lnps	0.4204	0.0911	4.61	0.000	0.2406	0.6003
lnrq	-0.1524	0.1155	-1.32	0.189	-0.3803	0.0755
mr	0.0353	0.0123	2.88	0.004	0.0111	0.0596
fdi	0.0023	0.0099	0.23	0.818	-0.0172	0.0218
lniva	0.0155	0.1842	0.08	0.933	-0.3480	0.3791
lnrdexp	-0.0101	0.0827	-0.12	0.903	-0.1734	0.1532
lnresrd	-0.0563	0.1992	-0.28	0.778	-0.4493	0.3367
lnsi	-1.1053	0.4453	-2.48	0.014	-1.9839	-0.2266
_cons	-1.0387	2.2792	-0.46	0.649	-5.5361	3.4586
sigma_u	1.3695					
sigma_e	0.3938					
rho	0.9236	(fraction of variance due to u_i)				
F-test that all u_i=0:	F(9,180)=60.20	Prob>F=0.0000				

Table 11.4: LDCs & other countries' copper market share random-effects model

Random-effects GLS regression					No. of obs =	200
Group variable: id_LDCs					No. of groups =	10
R-sq: within	= 0.0336				Obs per group: min =	20
Between	= 0.8621				avg =	20.0
overall	= 0.6810				max =	20
					Wald chi2(10) =	403.55
corr(u_i, X)	= 0 (assumed)				Prob>chi2 =	0.0000
lnshare	Coef.	Std. Err.	Z	P>l Z l	95% Conf.	Interval
lnepc	0.0509	0.1637	0.31	0.756	-0.2699	0.3716
eimp	-0.00001	0.0014	-0.01	0.993	-0.0029	0.0028
lnps	0.0084	0.0889	0.09	0.925	-0.1659	0.1826
lnrq	0.1400	0.1097	1.28	0.202	-0.0750	0.3550
mr	0.1207	0.0153	7.91	0.000	0.0908	0.1506
fdi	-0.0377	0.0165	-2.29	0.022	-0.0700	-0.0054
lniva	0.5929	0.1666	3.56	0.000	0.2665	0.9193
lnrdexp	-0.3066	0.0951	-3.22	0.001	-0.4930	-0.1202
lnresrd	0.7725	0.1233	6.27	0.000	0.5309	1.0142
lnsi	1.9461	0.3889	5.00	0.000	1.1839	2.7083
_cons	-9.7217	1.1124	-8.74	0.000	-11.9020	-7.5415
sigma_u	0					
sigma_e	0.3938					
rho	0	(fraction of variance due to u_i)				

Table 11.5: Summary of fixed-effects model results for all country groups

Variable	All Countries	OECD	BRICS	LDCs & Others
epc	0.5176**	1.1155*	1.7885***	0.4432
eimp	0.0002	-0.0191***	-0.0244***	0.0031
ps	0.3293***	-0.2242	-0.0721	0.4204***
rq	-0.2085*	1.2689	-1.4878***	-0.1524
mr	0.0494***	-0.0959	-0.0956	0.0353**
fdi	-0.0132	-0.0744**	-0.0929**	0.0023
iva	0.1691	0.3413	0.9787*	0.0155
rdexp	-0.1143	-0.9936***	-0.8393***	-0.0101
resrd	-0.3173*	0.9309***	0.5031*	-0.0563
si	-0.7288	-4.4130	-0.6192	-1.1053*
Legend: * p< .05; ** p< .01 ; *** p< 0.001				

11.1.1 Panel tests

To check the adequacy and validity of the empirical results obtained, a set of tests was performed, as follows:

Hausman test

The Hausman test is performed to select the best fit model between the fixed- and random-effects models. The test compares the coefficient estimates from the random-effects model to those from the fixed-effects model. The idea underlying the Hausman test is that both the random- and fixed-effects estimators are consistent if there is no correlation between the error term and the explanatory variables. If both estimators are consistent, then they should converge towards the true parameter given the values in large samples (Adekins & Carter, 2007).

The statistic test determined for the time-varying regressors test if there was a significant difference between the fixed- and random-effects models. The null hypotheses were as follows:

$H_0 = cov(X_{it}, \mu_i) = 0$ and

$H_0 = cov(X_{it}, \mu_i) \neq 0$.

The results of the Hausman tests for all groups of countries are presented in Table 11.6. The command (Hausman FE RE) with the Stata software performed the estimation for the choice of the best-fit model between the two.

Table 11.6: Hausman test results for the all-countries group

	Coefficients			
	(b) fe	(B) re	(b-B) Difference	Sqrt (diag(v_b-v_B)) S.E.
lnepc	0.5176	0.6120	-0.0944	0.0892841
eimp	0.0002	-0.0006	0.0008	0.0005868
lnps	0.3293	0.3285	0.0008	0.0168641
lnrq	-0.2085	-0.1441	-0.0645	0.0251671
mr	0.0494	0.0493	0.00016	0.0025251
fdi	-0.0132	-0.0157	0.0025	0.0016402
lniva	0.1691	0.1753	-0.0062	0.0620936
lnrdexp	-0.1143	-0.1244	0.0101	0.0170578
lnresrd	-0.3173	-0.2504	-0.0669	0.0403852
lnsi	-0.7288	-0.4970	-0.2318	0.1564702

b = Consistent under Ho and Ha; obtained from xtreg
B = Inconsistent under Ha; efficient under Ho; obtained from xtreg
Test: Ho: The difference in the coefficients is not systematic.
chi2(10) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 29.33
Prob>chi2 = 0.0011
(V_b-V_B is not positive definite)

In Table 11.6, this test statistic is asymptotically normal when the null hypothesis is true, and the critical value 1.96 is exceeded by the test statistic; thus, the equality of the two coefficients is rejected. The chi-square statistic compares all the 10 coefficients, which have small p-values, again leading to the rejection of the null hypothesis and acceptance of the alternative hypothesis. This suggests that the fixed-effects estimator is consistent and efficient.

Table 11.7: Summary of the Hausman test results for all country groups

	Chi2 (10)	**Prob>chi2**	**Conclusion**
All countries	29.33>1.96	0.0011<0.05	Fixed-effects model
OECD	156.03>1.96	0.0000<0.05	Fixed-effects model
BRICS	105.38>1.96	0.0000<0.05	Fixed-effects model
LDCs & others	866.68>1.96	0.0000<0.05	Fixed-effects model

Table 11.7 shows a summary of the Hausman test results for all the country groups. For the same reason as stated above for all countries, the other country groups (OECD, BRICS, and LDCs & others), following the results obtained, show that there is a significant difference between the random- and fixed-effects estimators. Hence, the null hypothesis is rejected and the alternative hypothesis that the fixed-effect model is consistent and efficient is accepted.

Testing for heteroskedasticity

Heteroskedasticity arises when the variance of the unobserved error depends on the explanatory variable. Therefore, the estimated model will not be able to get unbiased estimators of the *ceteris paribus* effects of the explanatory variable on the dependent variable (Wooldridge, 2009). The Stata software calculates a modified Wald test for groupwise heteroskedasticity in the fixed-effects regression model. The null hypothesis assumes homoscedasticity. The most likely deviation from the homoscedasticity errors in the context of the panel data is the error variances specific to the cross-sectional unit. The test was carried out for all the country groups, and evidence of homoscedasticity was found. As shown in Table 11.8, the null hypothesis of homoscedasticity is consistent for all the country groups.

Table 11.8: Heteroskedasticity test results for all country groups

All countries	Modified Wald test for groupwise heteroskedasticity in the fixed-effects regression model H0: sigma (i)^2 = sigma^2 for all i Chi2 (21) = 2800.87 Prob>chi2 = 0.0000
OECD	Modified Wald test for groupwise heteroskedasticity in the fixed-effects regression model H0: sigma (i)^2 = sigma^2 for all i Chi2 (6) = 70.05 Prob>chi2 = 0.0000
BRICS	Modified Wald test for groupwise heteroskedasticity in the fixed-effects regression model H0: sigma (i)^2 = sigma^2 for all i Chi2 (5) = 14.14 Prob>chi2 = 0.0147
LDCs & others	Modified Wald test for groupwise heteroskedasticity in the fixed-effects regression model H0: sigma (i)^2 = sigma^2 for all i Chi2 (10) = 1300.34 Prob>chi2 = 0.0000

11.2 Results analysis

The results in Table 11.6 show a robust statistical relationship between market share (dependent variable) and the explanatory variables in each country group.

Considering all the country groups, the political stability and government effectiveness (ps) and the mineral rents have the most positive influence on the market share at a 0.01 significance level, which confirms the authors' hypothesis. This implies that the more politically stable a country is, the higher the likelihood that its market share will increase. Again, the higher the revenue from mineral rents of a country is, the higher its tendency to increase the production of the commodity, and thus, to increase its market share.

Mineral rents offer governments, among other things, the financial resources to fund physical, social, and human capital. It is expected that as the income realized from copper sales by copper-producing countries increases, their investment in capacity addition and expansion also increases. Davis (2005) argued that the use of rents is critical in determining whether or not mining promotes economic development. When they are squandered by corruption, war, and other rent-seeking activities, mining is likely to be a negative rather than positive force of development. The same is true when the rents are wastefully consumed rather than invested in alternative forms of capital.

Energy consumption has a strong influence on copper production at a 0.01 significance level. The first saleable product of mining is concentrates, which are manufactured from mineral ores. Ores are concentrations of mineralization located either proximate to the surface or underground. Therefore, the technology of mineral ore extraction and the process of concentrate refining is energy-intensive (Davis, 2009). The result also confirms that the increase in energy consumption will impact on the expansion of mining production.

The quality of a country's institutional and regulatory framework impacts the production. When the regulatory framework is weak, investors have an incentive to manipulate their operations for increased profitability, due to the externalities in production. Fuelled by rent-seeking and likely corrupt practices, Kolstad and Soreide (2009) argued that the extraction of certain resources provides the central government with substantial revenues. As in other areas of taxation or revenue collection, this creates incentives for embezzlement of revenues by government officials, or for collusion on tax evasion by private firms and individuals.

Furthermore, the investors usually have the best technical, commercial, and financial knowledge of the mining sector in most developing countries. As a consequence, the regulatory institutions do rely on foreign investors, represented by multinational mining companies, for their capacity building. This can result in misguidance and Iow compliance with the host countries' technical and operational regulations.

The R&D personnel (per million people) have strong statistical significance but have a negative relationship with market share. This can be explained by the fact that the big market share is from the LDCs and other countries, which accounts for around 60%, and these countries have a smaller number of R&D personnel compared to the OECD and BRICS country groups. This is confirmed by the results shown in the same table where the positive influence of this variable is shown for the OECD and BRICS countries. The negative influence of R&D on copper production share indicates that the global mineral mining industry uses homogenous technologies provided by technology vendors. Whether a country has its own mining technology or does not have one has no influence on the country's copper production capacity expansion. Evidently, about 65% of the global copper production is from LDCs and other countries that have low R&D capacity and capability.

With regard to the LDCs and other countries, a very strong positive influence of political stability and government effectiveness (ps) on the market share is noticed, which confirms the authors' hypothesis. This suggests that the governance vector is a critical factor for this country group.

Mineral rent has a strong positive impact on copper production increase, which also confirms the authors' hypothesis. This explains the fact that most governments rely heavily on their copper earnings to fund their national budgets. To maintain this, efforts need to be directed to expanding the higher technical skills required by the minerals industry. Public support is required for innovation in the fields related to natural-resource exploitation through national innovation systems, such as tax incentivization of local R&D and technician human resource development, as well as for the allocation of some resource rents to developing technological linkages (UNECA, 2011). The mining sector development policy should target increasing the country's reserves of newly discovered deposits.

The negative influence of the strength of the investor protection index on copper production suggests that this variable is not a determinant in the LDCs & others country group, but it can increase the share if complemented by other socioeconomic and policy factors.

Chapter 12. Conclusion and Policy Implications

12.1 Summary

This study investigated the effectiveness of the drivers of market share increase of copper production from upstream-producing countries in the international copper market via panel data analysis for a set of 21 countries spanning 20 years, from 1991 to 2010. The fixed- and random-effects models were applied. The determinants were categorized as governance, socioeconomic, and country-specific factors. Four country groups were analyzed: all countries, OECD countries, BRICS countries, and LDCs & others.

The empirical model on the determinants of copper market share increase showed results that are consistent with the authors' hypothesis that governance has a crucial role in a country's mineral development. This is consistent with the findings of Brunnschweiller (2008) and the conclusions of Pessoa (2008).

12.2 Keys findings and policy implications for DRC as a copper producer

In this study, it was found that some determinants have significant effects on the market share of each country's copper production. In the all-countries and LDCs & others country groups, variables such as energy consumption, political stability, and mineral rents are positively significant determinants of market share increase. The other variables, such as energy import, foreign direct investment (net inflow), industry value added, R&D

expenditures, and strength of investor protection index, were found not to be statistically significant variables.

The empirical model of the determinants of copper market share increase showed results that are consistent with the authors' hypothesis that governance has a crucial role in a country's mineral development. Therefore, strong and stable political institutions are conditions for growth. Thus, governance policy plays a crucial role in increasing the market share. Therefore, successful linkage development will rely on simultaneous multifactor promotion: skills, savings, business performance, government effectiveness, policymaking, and implementation capacity. This means having to build backward and forward linkages, which requires creating the business environment and public-sector institutions that foster growth.

The reform policies of the government should focus on strengthening regulatory institutions through capacity building and by ensuring transparency and accountability. Evidently, endorsing and institutionalizing the Extractive Industries Transparency Initiative (EITI) can be desirable in this regard. Mineral rent has a strong positive impact on copper production increase. This also confirmed the authors' hypothesis. This suggests and explains why most governments rely heavily on their copper earnings to fund their national budgets.

As a consequence, a country must strive to increase its copper production to increase its income through mineral rent. Considering the exhaustive nature of mineral resources, the government policy should focus on re-investing a significant proportion of its mineral rent in developing the non-mineral sectors for greater economic growth and sustainable development ventures to cater to the future generation.

The national policies should focus on strengthening democracy and the political process that can lead to a stable political system. The socioeconomic policies should also focus on the equitable distribution of mineral rents within the country.

Mineral development is an integral part of the broader process of national economic development. To raise the minerals economy, the government should consider the following elements: an accommodating legal environment, investment in the public-knowledge infrastructure, investment in mining-related education (e.g., geology, mining, minerals, metallurgy, environment sciences), strengthening government institutions and capacity building, improving the state of the country's geological information and data, and the social and environmental issues and concerns in conformity with the internationally recognized norms for environmental protection and the social conditions in the mining areas.

Limitations and recommendations for further study

This research is limited in that it did not take into consideration other appropriate factors that also significantly influence copper production, due to the lack of available data and the complexity of the mineral sectors of different countries. Further research is thus needed in this field of minerals, such as that assessing the ways that the current reform processes affect the performance of the mineral markets as well as the institutional choice patterns of the mining sector. This will provide more insight into the political ecology of the natural-resource markets in countries emerging from protracted armed conflicts, specifically the Democratic Republic of the Congo.

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Appendices

Appendix 1: Cointegration analysis results

Unit root tests using Augmented Dickey-Fuller statistics (ADF)

Table A-1: Unit root test for GDP

Dickey-Fuller test for unit root Number of obs = 40

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-0.843	-3.648	-2.958	-2.612

MacKinnon approximate p-value for Z(t) = 0.8061

Table A-1.1: Unit root test for GDP avec trend

Dickey-Fuller test for unit root Number of obs = 40

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-0.669	-4.242	-3.540	-3.204

MacKinnon approximate p-value for Z(t) = 0.9751

Table A-1.2: Unit root test for 1st difference GDP

Dickey-Fuller test for unit root Number of obs = 39

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-2.986	-3.655	-2.961	-2.613

MacKinnon approximate p-value for Z(t) = 0.0362

Table A-1.3: Unit root test for 1st difference GDP avec trend

Dickey-Fuller test for unit root Number of obs = 39

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-3.008	-4.251	-3.544	-3.206

MacKinnon approximate p-value for Z(t) = 0.1299

Table A-2: Unit root test for Entco

Dickey-Fuller test for unit root Number of obs = 40

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-1.164	-4.242	-3.540	-3.204

MacKinnon approximate p-value for Z(t) = 0.9176

Table A-2.1: Unit root test for Entco avec trend

Dickey-Fuller test for unit root Number of obs = 40

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-1.164	-4.242	-3.540	-3.204

MacKinnon approximate p-value for Z(t) = 0.9176

Table A-2.2: Unit root test for 1st difference Entco

Dickey-Fuller test for unit root Number of obs = 39

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-5.426	-3.655	-2.961	-2.613

MacKinnon approximate p-value for Z(t) = 0.0000

Table A-2.3: Unit root test for 1st difference Entco avec trend

Dickey-Fuller test for unit root Number of obs = 39

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-5.416	-4.251	-3.544	-3.206

MacKinnon approximate p-value for Z(t) = 0.0000

Table A-3: Unit root test for coprod

Dickey-Fuller test for unit root Number of obs = 40

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-0.689	-3.648	-2.958	-2.612

MacKinnon approximate p-value for Z(t) = 0.8497

Table A-3.1: Unit root test for coprod avec trend

Dickey-Fuller test for unit root Number of obs = 40

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	0.540	-4.242	-3.540	-3.204

MacKinnon approximate p-value for Z(t) = 0.9969

Table A-3.2: Unit root test for 1st difference coprod

Dickey-Fuller test for unit root Number of obs = 39

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-2.998	-3.655	-2.961	-2.613

MacKinnon approximate p-value for Z(t) = 0.0351

Table A-3.3: Unit root test for 1st difference coprod avec trend

Dickey-Fuller test for unit root — Number of obs = 39

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-3.165	-4.251	-3.544	-3.206

MacKinnon approximate p-value for Z(t) = 0.0916

Table A-4: Unit root test for price

Dickey-Fuller test for unit root — Number of obs = 40

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-1.818	-3.648	-2.958	-2.612

MacKinnon approximate p-value for Z(t) = 0.3715

Table A-4.1: Unit root test for price avec trend

Dickey-Fuller test for unit root — Number of obs = 40

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-1.342	-4.242	-3.540	-3.204

MacKinnon approximate p-value for Z(t) = 0.8770

Table A-4.2: Unit root test for 1st difference price

Dickey-Fuller test for unit root — Number of obs = 39

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-5.457	-3.655	-2.961	-2.613

MacKinnon approximate p-value for Z(t) = 0.0000

Table A-4.3: Unit root test for 1st difference price avec trend

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Dickey-Fuller test for unit root Number of obs = 39

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-5.647	-4.251	-3.544	-3.206

MacKinnon approximate p-value for Z(t) = 0.0000

Unit root tests using Philip-Perron statistics (PP)

Table A-5: Unit root test for GDP

Phillips-Perron test for unit root Number of obs = 40
Newey-West lags = 3

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(rho)	-3.792	-18.220	-12.980	-10.500
Z(t)	-1.350	-3.648	-2.958	-2.612

MacKinnon approximate p-value for Z(t) = 0.6058

Table A-5.1: Unit root test for GDP avec trend

Phillips-Perron test for unit root Number of obs = 40
Newey-West lags = 3

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(rho)	-5.606	-24.420	-19.040	-16.320
Z(t)	-1.501	-4.242	-3.540	-3.204

MacKinnon approximate p-value for Z(t) = 0.8287

Table A-5.2: Unit root test for 1st difference GDP

Phillips-Perron test for unit root — Number of obs = 39; Newey-West lags = 3

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
		Interpolated Dickey-Fuller		
Z(rho)	-15.331	-18.152	-12.948	-10.480
Z(t)	-2.994	-3.655	-2.961	-2.613

MacKinnon approximate p-value for Z(t) = 0.0355

Table A-5.3: Unit root test for 1st difference GDP avec trend

Phillips-Perron test for unit root — Number of obs = 39; Newey-West lags = 3

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
		Interpolated Dickey-Fuller		
Z(rho)	-14.818	-24.292	-18.964	-16.272
Z(t)	-2.964	-4.251	-3.544	-3.206

MacKinnon approximate p-value for Z(t) = 0.1424

Table A-6: Unit root test for Entco

Phillips-Perron test for unit root — Number of obs = 40; Newey-West lags = 3

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
		Interpolated Dickey-Fuller		
Z(rho)	-6.207	-18.220	-12.980	-10.500
Z(t)	-1.444	-3.648	-2.958	-2.612

MacKinnon approximate p-value for Z(t) = 0.5611

Table A-6.1: Unit root test for Entco avec trend

Phillips-Perron test for unit root — Number of obs = 40; Newey-West lags = 3

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(rho)	-6.654	-24.420	-19.040	-16.320
Z(t)	-1.526	-4.242	-3.540	-3.204

MacKinnon approximate p-value for Z(t) = 0.8202

Table A-6.2: Unit root test for 1st difference Entco

Phillips-Perron test for unit root — Number of obs = 39; Newey-West lags = 3

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(rho)	-34.847	-18.152	-12.948	-10.480
Z(t)	-5.424	-3.655	-2.961	-2.613

MacKinnon approximate p-value for Z(t) = 0.0000

Table A-6.3: Unit root test for 1st difference Entco avec trend

Phillips-Perron test for unit root — Number of obs = 39; Newey-West lags = 3

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(rho)	-34.524	-24.292	-18.964	-16.272
Z(t)	-5.404	-4.251	-3.544	-3.206

MacKinnon approximate p-value for Z(t) = 0.0000

Table A-7: Unit root test for coprod

Phillips-Perron test for unit root — Number of obs = 40; Newey-West lags = 3

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(rho)	-3.002	-18.220	-12.980	-10.500
Z(t)	-1.162	-3.648	-2.958	-2.612

MacKinnon approximate p-value for Z(t) = 0.6898

Table A-7.1: Unit root test for coprod avec trend

Phillips-Perron test for unit root — Number of obs = 40; Newey-West lags = 3

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
		Interpolated Dickey-Fuller		
Z(rho)	-2.255	-24.420	-19.040	-16.320
Z(t)	-0.618	-4.242	-3.540	-3.204

MacKinnon approximate p-value for Z(t) = 0.9780

Table A-7.2: Unit root test for 1st difference coprod

Phillips-Perron test for unit root — Number of obs = 39; Newey-West lags = 3

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
		Interpolated Dickey-Fuller		
Z(rho)	-20.142	-18.152	-12.948	-10.480
Z(t)	-3.073	-3.655	-2.961	-2.613

MacKinnon approximate p-value for Z(t) = 0.0286

Table A-7.3: Unit root test for 1st difference coprod avec trend

Phillips-Perron test for unit root — Number of obs = 39; Newey-West lags = 3

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
		Interpolated Dickey-Fuller		
Z(rho)	-20.313	-24.292	-18.964	-16.272
Z(t)	-3.173	-4.251	-3.544	-3.206

MacKinnon approximate p-value for Z(t) = 0.0900

Table A-8: Unit root test for price

Phillips-Perron test for unit root — Number of obs = 40; Newey-West lags = 3

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
		Interpolated Dickey-Fuller		
Z(rho)	-7.433	-18.220	-12.980	-10.500
Z(t)	-1.926	-3.648	-2.958	-2.612

MacKinnon approximate p-value for Z(t) = 0.3201

Table A-8.1: Unit root test for price avec trend

```
Phillips-Perron test for unit root                   Number of obs   =        40
                                                     Newey-West lags =         3
```

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(rho)	-5.198	-24.420	-19.040	-16.320
Z(t)	-1.341	-4.242	-3.540	-3.204

MacKinnon approximate p-value for Z(t) = 0.8775

Table A-8.2: Unit root test for 1st difference price

```
Phillips-Perron test for unit root                   Number of obs   =        39
                                                     Newey-West lags =         3
```

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(rho)	-33.807	-18.152	-12.948	-10.480
Z(t)	-5.397	-3.655	-2.961	-2.613

MacKinnon approximate p-value for Z(t) = 0.0000

Table A-8.3: Unit root test for 1st difference price avec trend

```
Phillips-Perron test for unit root                   Number of obs   =        39
                                                     Newey-West lags =         3
```

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(rho)	-33.590	-24.292	-18.964	-16.272
Z(t)	-5.588	-4.251	-3.544	-3.206

MacKinnon approximate p-value for Z(t) = 0.0000

Lag length selection criteria

Table B-1: lag length Selection-order criteria result for gdp

Selection-order criteria
Sample: 1974 - 2010 Number of obs = 37

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-473.416				8.0e+09	25.6441	25.6594	25.6876
1	-425.363	96.105	1	0.000	6.3e+08	23.1007	23.1314	23.1878
2	-414.146	22.434*	1	0.000	3.6e+08*	22.5484*	22.5945*	22.679*
3	-414.134	.02341	1	0.878	3.8e+08	22.6018	22.6632	22.776
4	-412.66	2.948	1	0.086	3.7e+08	22.5762	22.653	22.7939

Endogenous: gdp
Exogenous: _cons

Table B-2: lag length Selection-order criteria result for Entco

Selection-order criteria
Sample: 1974 - 2010 Number of obs = 37

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-476.713				9.6e+09	25.8223	25.8377	25.8659
1	-455.029	43.368*	1	0.000	3.1e+09*	24.7043*	24.735*	24.7914*
2	-454.634	.7896	1	0.374	3.2e+09	24.737	24.783	24.8676
3	-453.95	1.3696	1	0.242	3.3e+09	24.754	24.8154	24.9282
4	-453.582	.73552	1	0.391	3.4e+09	24.7882	24.865	25.0059

Endogenous: Entco
Exogenous: _cons

Table B-3: lag length Selection-order criteria result for coprod

Selection-order criteria
Sample: 1974 - 2010 Number of obs = 37

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-504.933				4.4e+10	27.3477	27.3631	27.3913
1	-456.763	96.341	1	0.000	3.4e+09	24.798	24.8287	24.8851
2	-452.357	8.8101	1	0.003	2.9e+09	24.6139	24.66	24.7445
3	-447.956	8.8037*	1	0.003	2.4e+09*	24.43*	24.4914*	24.6042*
4	-447.954	.00239	1	0.961	2.5e+09	24.484	24.5608	24.7017

Endogenous: coprod
Exogenous: _cons

Johansen cointegration tests

Table C-1: Johansen cointegration test for gdp & Entco

Johansen tests for cointegration

Trend: constant — Number of obs = 39

Sample: 1972 - 2010 — Lags = 2

maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value
0	6	-911.25493	.	7.9676*	15.41
1	9	-908.85635	0.11574	3.1705	3.76
2	10	-907.27112	0.07808		

maximum rank	parms	LL	eigenvalue	max statistic	5% critical value
0	6	-911.25493	.	4.7972	14.07
1	9	-908.85635	0.11574	3.1705	3.76
2	10	-907.27112	0.07808		

Table C-2: Johansen cointegration test for gdp & coprod

Johansen tests for cointegration

Trend: constant — Number of obs = 39

Sample: 1972 - 2010 — Lags = 2

maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value
0	6	-906.37426	.	10.9766*	15.41
1	9	-902.01295	0.20041	2.2539	3.76
2	10	-900.88598	0.05616		

maximum rank	parms	LL	eigenvalue	max statistic	5% critical value
0	6	-906.37426	.	8.7226	14.07
1	9	-902.01295	0.20041	2.2539	3.76
2	10	-900.88598	0.05616		

Table C-3: Johansen cointegration test for coprod & Entco

Johansen tests for cointegration

Trend: constant — Number of obs = 39

Sample: 1972 - 2010 — Lags = 2

maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value
0	6	-951.60185	.	5.7191*	15.41
1	9	-949.36371	0.10843	1.2429	3.76
2	10	-948.74228	0.03137		

maximum rank	parms	LL	eigenvalue	max statistic	5% critical value
0	6	-951.60185	.	4.4763	14.07
1	9	-949.36371	0.10843	1.2429	3.76
2	10	-948.74228	0.03137		

Table C-4: Johansen cointegration test for coprod & price

Johansen tests for cointegration

Trend: constant — Number of obs = 39

Sample: 1972 - 2010 — Lags = 2

maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value
0	6	-783.59237	.	8.2451*	15.41
1	9	-780.13596	0.16243	1.3323	3.76
2	10	-779.46982	0.03358		

maximum rank	parms	LL	eigenvalue	max statistic	5% critical value
0	6	-783.59237	.	6.9128	14.07
1	9	-780.13596	0.16243	1.3323	3.76
2	10	-779.46982	0.03358		

Table C-5: Johansen cointegration test for gdp & price

Johansen tests for cointegration

Trend: constant — Number of obs = 39

Sample: 1972 - 2010 — Lags = 2

maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value
0	6	-749.59283	.	7.1121*	15.41
1	9	-747.37969	0.10729	2.6858	3.76
2	10	-746.03678	0.06655		

maximum rank	parms	LL	eigenvalue	max statistic	5% critical value
0	6	-749.59283	.	4.4263	14.07
1	9	-747.37969	0.10729	2.6858	3.76
2	10	-746.03678	0.06655		

Table C-6: Johansen cointegration test for gdp , Entco & coprod

Johansen tests for cointegration

Trend: constant — Number of obs = 39

Sample: 1972 - 2010 — Lags = 2

maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value
0	12	-1376.7751	.	24.0310*	29.68
1	17	-1368.471	0.34678	7.4229	15.41
2	20	-1365.9814	0.11986	2.4436	3.76
3	21	-1364.7596	0.06073		

maximum rank	parms	LL	eigenvalue	max statistic	5% critical value
0	12	-1376.7751	.	16.6081	20.97
1	17	-1368.471	0.34678	4.9793	14.07
2	20	-1365.9814	0.11986	2.4436	3.76
3	21	-1364.7596	0.06073		

Vector Autoregression Models (VAR-D)

Table D-1: VAR estimates of Dgdp and DEntco models

Sample: 1974 - 2010		No. of obs	= 37
Log likelihood = -863.3981		AIC	= 47.21071
FPE = 1.10e+18		HQIC	= 47.3642
Det(Sigma_ml) = 6.36e+17		SBIC	= 47.64609

Equation	Parms	RMSE	R-sq	chi2	P>chi2
dgdp	5	18646.7	0.4966	36.49475	0.0000
dEntco	5	49466.6	0.2524	12.49249	0.0140

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
dgdp						
dgdp						
L1.	.6371194	.1576699	4.04	0.000	.3280921	.9461466
L2.	-.2371382	.1584009	-1.50	0.134	-.5475984	.0733219
dEntco						
L1.	.1789311	.0618254	2.89	0.004	.0577555	.3001066
L2.	.0202725	.0616522	0.33	0.742	-.1005636	.1411087
_cons	-1684.488	2933.551	-0.57	0.566	-7434.143	4065.167
dEntco						
dgdp						
L1.	1.323554	.4182722	3.16	0.002	.5037558	2.143353
L2.	-.180412	.4202116	-0.43	0.668	-1.004012	.6431876
dEntco						
L1.	-.060871	.1640126	-0.37	0.711	-.3823298	.2605878
L2.	-.1447421	.1635532	-0.88	0.376	-.4653004	.1758162
_cons	10106.59	7782.229	1.30	0.194	-5146.301	25359.48

Table D-2: VAR estimates of Dgdp and Dcoprod models

Sample: 1974 - 2010			No. of obs	=	37
Log likelihood = -856.3374			AIC	=	46.82905
FPE = 7.48e+17			HQIC	=	46.98254
Det(Sigma_ml) = 4.34e+17			SBIC	=	47.26443

Equation	Parms	RMSE	R-sq	chi2	P>chi2
dgdp	5	16506.3	0.6055	56.79098	0.0000
dcoprod	5	47935.6	0.3710	21.82738	0.0002

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
dgdp						
dgdp						
L1.	.3086442	.1657785	1.86	0.063	-.0162757	.6335641
L2.	-.051007	.1320043	-0.39	0.699	-.3097306	.2077167
dcoprod						
L1.	.2500165	.0612773	4.08	0.000	.1299153	.3701177
L2.	.0521379	.0778063	0.67	0.503	-.1003596	.2046355
_cons	381.8392	2530.559	0.15	0.880	-4577.964	5341.643
dcoprod						
dgdp						
L1.	-.7927695	.4814342	-1.65	0.100	-1.736363	.1508243
L2.	.4908511	.3833511	1.28	0.200	-.2605033	1.242205
dcoprod						
L1.	.301684	.1779541	1.70	0.090	-.0470997	.6504677
L2.	.5775952	.2259558	2.56	0.011	.1347299	1.02046
_cons	1171.238	7348.947	0.16	0.873	-13232.43	15574.91

Table D-3: VAR estimates of Dcoprod and DEntco models

Sample: 1974 - 2010			No. of obs	=	37
Log likelihood = -894.1133			AIC	=	48.87099
FPE = 5.77e+18			HQIC	=	49.02448
Det(Sigma_ml) = 3.35e+18			SBIC	=	49.30637

Equation	Parms	RMSE	R-sq	chi2	P>chi2
dcoprod	5	41198.9	0.5354	42.63871	0.0000
dEntco	5	53126.1	0.1377	5.909018	0.2060

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
dcoprod						
dcoprod						
L1.	.3638378	.1630678	2.23	0.026	.0442308	.6834448
L2.	.4697762	.154494	3.04	0.002	.1669736	.7725789
dEntco						
L1.	.2618792	.1319281	1.99	0.047	.0033049	.5204535
L2.	-.46179	.1403679	-3.29	0.001	-.7369061	-.1866739
_cons	2643.293	6513.402	0.41	0.685	-10122.74	15409.33
dEntco						
dcoprod						
L1.	.2835344	.210276	1.35	0.178	-.1285991	.6956679
L2.	.2394621	.1992201	1.20	0.229	-.1510022	.6299264
dEntco						
L1.	-.1001285	.1701214	-0.59	0.556	-.4335602	.2333033
L2.	-.1020105	.1810046	-0.56	0.573	-.456773	.2527519
_cons	10171.57	8399.038	1.21	0.226	-6290.239	26633.39

Table D-4: VAR estimates of Dcoprod and Dprice models

Sample: 1973 - 2010		No. of obs	= 38
Log likelihood	= -758.9749	AIC	= 40.47236
FPE	= 1.30e+15	HQIC	= 40.62569
Det(Sigma_ml)	= 7.65e+14	SBIC	= 40.90331

Equation	Parms	RMSE	R-sq	chi2	P>chi2
dcoprod	5	46478	0.4034	25.69202	0.0000
dprice	5	730.252	0.1357	5.966825	0.2016

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
dcoprod						
dcoprod						
L1.	.0904269	.1892208	0.48	0.633	-.2804391	.4612929
L2.	.610841	.1798098	3.40	0.001	.2584203	.9632616
dprice						
L1.	24.16992	11.02469	2.19	0.028	2.561923	45.77792
L2.	4.528528	11.49072	0.39	0.694	-17.99287	27.04992
_cons	2227.957	7037.54	0.32	0.752	-11565.37	16021.28
dprice						
dcoprod						
L1.	-.0066536	.002973	-2.24	0.025	-.0124806	-.0008267
L2.	.0054275	.0028251	1.92	0.055	-.0001096	.0109647
dprice						
L1.	.2060203	.1732174	1.19	0.234	-.1334794	.5455201
L2.	.0288895	.1805395	0.16	0.873	-.3249615	.3827404
_cons	23.22807	110.5722	0.21	0.834	-193.4894	239.9456

Granger causality tests.

Table E-1: Granger causality test results for gdp & Entco

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
dgdp	dEntco	8.3764	2	0.015
dgdp	ALL	8.3764	2	0.015
dEntco	dgdp	11.799	2	0.003
dEntco	ALL	11.799	2	0.003

Table E-2: Granger causality test results for gdp & coprod

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
dgdp	dcoprod	20.908	2	0.000
dgdp	ALL	20.908	2	0.000
dcoprod	dgdp	3.2186	2	0.200
dcoprod	ALL	3.2186	2	0.200

Table E-3: Granger causality test results for coprod & Entco

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
dcoprod	dEntco	17.447	2	0.000
dcoprod	ALL	17.447	2	0.000
dEntco	dcoprod	5.3076	2	0.070
dEntco	ALL	5.3076	2	0.070

Table E-4: Granger causality test results for coprod & price

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
dcoprod	dprice	5.1717	2	0.075
dcoprod	ALL	5.1717	2	0.075
dprice	dcoprod	5.5657	2	0.062
dprice	ALL	5.5657	2	0.062

Appendix 2: Panel data analysis results

Table F-1: Correlation matrix of variables

	epc	eimp	ps	rq	mr	fdi	iva
epc	1.0000						
eimp	-0.1810	1.0000					
ps	0.6175	0.1897	1.0000				
rq	0.5725	0.3245	0.7431	1.0000			
mr	-0.2159	0.1093	-0.0153	-0.0456	1.0000		
fdi	-0.0372	0.2279	0.0972	0.0054	0.1444	1.0000	
iva	-0.0826	-0.3309	-0.1352	-0.1267	0.1097	-0.5999	1.0000
resrd	0.8671	0.0111	0.6113	0.5644	-0.2351	-0.0247	-0.1280
si	0.5598	0.1607	0.4622	0.6659	-0.0375	0.0344	-0.1515

	resrd	si
resrd	1.0000	
si	0.3538	1.0000

Fixed and random effects models

Table F-2: BRICS countries copper market share fixed effects model

```
Fixed-effects (within) regression               Number of obs      =       100
Group variable: id_BRICS                        Number of groups   =         5

R-sq:  within  = 0.5740                         Obs per group: min =        20
       between = 0.5715                                        avg =      20.0
       overall = 0.5438                                        max =        20

                                                F(10,85)           =     11.45
corr(u_i, Xb)  = -0.9099                        Prob > F           =    0.0000
```

lnshare	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnepc	1.788449	.4472106	4.00	0.000	.8992745	2.677623
eimp	-.0244251	.0038786	-6.30	0.000	-.0321369	-.0167134
lnps	-.072099	.1851419	-0.39	0.698	-.4402106	.2960126
lnrq	-1.487755	.2787429	-5.34	0.000	-2.04197	-.9335393
mr	-.0956163	.0579665	-1.65	0.103	-.2108692	.0196365
fdi	-.0928882	.0280559	-3.31	0.001	-.1486708	-.0371055
lniva	.9786788	.4502628	2.17	0.033	.0834359	1.873922
lnrdexp	-.8393148	.2236299	-3.75	0.000	-1.283951	-.3946787
lnresrd	.5030662	.24169	2.08	0.040	.0225217	.9836107
lnsi	-.6191938	1.523732	-0.41	0.685	-3.648781	2.410394
_cons	-12.29396	3.528446	-3.48	0.001	-19.30946	-5.278464
sigma_u	2.1905712					
sigma_e	.3013313					
rho	.98142911	(fraction of variance due to u_i)				

```
F test that all u_i=0:     F(4, 85) =     23.91              Prob > F = 0.0000
```

Table F-3: BRICS countries copper market share random effects model

```
Random-effects GLS regression                   Number of obs      =       100
Group variable: id_BRICS                        Number of groups   =         5

R-sq:  within  = 0.2034                         Obs per group: min =        20
       between = 0.9961                                        avg =      20.0
       overall = 0.8986                                        max =        20

                                                Wald chi2(10)      =    788.77
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000
```

lnshare	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lnepc	.4370955	.3264378	1.34	0.181	-.2027109	1.076902
eimp	-.0115132	.0038288	-3.01	0.003	-.0190175	-.004009
lnps	.5340157	.1423236	3.75	0.000	.2550666	.8129649
lnrq	-1.359142	.3537337	-3.84	0.000	-2.052447	-.6658364
mr	.0452498	.0666732	0.68	0.497	-.0854273	.175927
fdi	-.016449	.0371318	-0.44	0.658	-.089226	.0563279
lniva	3.569527	.3347898	10.66	0.000	2.913351	4.225703
lnrdexp	.1334481	.2493686	0.54	0.593	-.3553054	.6222015
lnresrd	-.1912029	.2485555	-0.77	0.442	-.6783628	.2959569
lnsi	-1.294381	.9052362	-1.43	0.153	-3.068612	.4798489
_cons	-8.542741	2.119022	-4.03	0.000	-12.69595	-4.389534
sigma_u	0					
sigma_e	.3013313					
rho	0	(fraction of variance due to u_i)				

Table F-4: OECD countries copper market share fixed effects model

```
Fixed-effects (within) regression               Number of obs      =       120
Group variable: id_OECD                         Number of groups   =         6

R-sq:  within  = 0.3797                         Obs per group: min =        20
       between = 0.4794                                        avg =      20.0
       overall = 0.4606                                        max =        20

                                                F(10,104)          =      6.37
corr(u_i, Xb)  = -0.6411                        Prob > F           =    0.0000
```

lnshare	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lnepc	1.115525	.49548	2.25	0.026	.1329696	2.09808
eimp	-.0190775	.0038484	-4.96	0.000	-.026709	-.0114459
lnps	-.2242152	.1852619	-1.21	0.229	-.5915965	.1431662
lnrq	1.268979	1.09588	1.16	0.250	-.9041928	3.44215
mr	-.0959168	.0632422	-1.52	0.132	-.2213285	.0294948
fdi	-.074381	.0264311	-2.81	0.006	-.1267949	-.0219671
lniva	.3412824	.4096337	0.83	0.407	-.4710366	1.153601
lnrdexp	-.9935755	.2318524	-4.29	0.000	-1.453348	-.5338035
lnresrd	.9308841	.2587037	3.60	0.000	.417865	1.443903
lnsi	-4.412998	4.84631	-0.91	0.365	-14.02341	5.197417
_cons	-11.58047	9.214858	-1.26	0.212	-29.85387	6.692944
sigma_u	1.1957522					
sigma_e	.33119827					
rho	.92874883	(fraction of variance due to u_i)				

```
F test that all u_i=0:     F(5, 104) =     24.58              Prob > F = 0.0000
```

Table F-5: OECD countries copper market share random effects model

```
Random-effects GLS regression                   Number of obs      =       120
Group variable: id_OECD                         Number of groups   =         6

R-sq:  within  = 0.0196                         Obs per group: min =        20
       between = 0.9884                                        avg =      20.0
       overall = 0.8596                                        max =        20

                                                Wald chi2(10)      =    667.39
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000
```

lnshare	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
lnepc	-.2351106	.1618282	-1.45	0.146	-.552288	.0820668
eimp	-.0075632	.0030324	-2.49	0.013	-.0135067	-.0016198
lnps	.2548699	.1338691	1.90	0.057	-.0075087	.5172484
lnrq	-2.396989	.9489195	-2.53	0.012	-4.256837	-.5371406
mr	-.0134644	.0691706	-0.19	0.846	-.1490363	.1221076
fdi	.0347287	.0324992	1.07	0.285	-.0289686	.0984261
lniva	2.652371	.4249774	6.24	0.000	1.819431	3.485311
lnrdexp	-.3724171	.2703572	-1.38	0.168	-.9023075	.1574733
lnresrd	.3586067	.1456852	2.46	0.014	.073069	.6441443
lnsi	2.117773	.9226667	2.30	0.022	.3093792	3.926166
_cons	-3.684442	4.916192	-0.75	0.454	-13.32	5.951116
sigma_u	0					
sigma_e	.33119827					
rho	0	(fraction of variance due to u_i)				

Hausman test

Table G-1: Hausman test result for All countries

```
. hausman fe re
```

	Coefficients (b) fe	(B) re	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
lnepc	.5176326	.6120029	-.0943703	.0892841
eimp	.0002059	-.00055	.0007559	.0005868
lnps	.3292766	.3284819	.0007947	.0168641
lnrq	-.2085491	-.1440808	-.0644683	.0251671
mr	.0494172	.0492581	.0001591	.0025251
fdi	-.013248	-.0156911	.0024431	.0016402
lniva	.1690656	.1752805	-.0062149	.0620936
lnrdexp	-.1143324	-.1244188	.0100863	.0170578
lnresrd	-.3172901	-.2504387	-.0668514	.0403852
lnsi	-.728768	-.4969822	-.2317858	.1564702

```
                    b = consistent under Ho and Ha; obtained from xtreg
     B = inconsistent under Ha, efficient under Ho; obtained from xtreg

   Test:  Ho:  difference in coefficients not systematic

              chi2(10) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                       =       29.33
             Prob>chi2 =      0.0011
             (V_b-V_B is not positive definite)
```

Table G-2: Summary of Fixed Effects model results for All countries

Variable	fe
lnepc	.51763256**
eimp	.00020593
lnps	.32927662***
lnrq	-.20854907*
mr	.04941724***
fdi	-.01324803
lniva	.16906562
lnrdexp	-.11433244
lnresrd	-.3172901**
lnsi	-.72876804
_cons	-.80103632

legend: * p<.05; ** p<.01; *** p<.001

Table G-3: Hausman test result for LDCs & other countries

```
. hausman fe re

                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |      fe           re          Difference          S.E.
-------------+----------------------------------------------------------------
       lnepc |    .4431568     .0508951        .3922617        .2326782
        eimp |    .0031497    -.0000127        .0031624         .001551
        lnps |    .4204236      .008369        .4120546        .0200453
        lnrq |   -.1524038     .1400194       -.2924233        .0360852
          mr |    .0353501     .1207239       -.0853738               .
         fdi |    .0022837    -.0377265        .0400102               .
       lniva |    .0155205     .5928888       -.5773683        .0787844
     lnrdexp |   -.0100873    -.3065827        .2964955               .
     lnresrd |   -.0563089     .7725298       -.8288387        .1564476
        lnsi |   -1.105279     1.946115       -3.051394        .2168913
------------------------------------------------------------------------------
                          b = consistent under Ho and Ha; obtained from xtreg
           B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(10) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                           =      866.68
                 Prob>chi2 =      0.0000
                 (V_b-V_B is not positive definite)
```

Table G-4: Summary of Fixed Effects model results for LDCs & Others

Variable	fe
lnepc	.44315681
eimp	.0031497
lnps	.42042356***
lnrq	-.15240383
mr	.03535012**
fdi	.00228372
lniva	.01552046
lnrdexp	-.01008725
lnresrd	-.05630892
lnsi	-1.1052789*
_cons	-1.0387299

legend: * p<.05; ** p<.01; *** p<.001

.

Table G-5: Hausman test result for BRICS countries

```
. hausman fe re

                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |      fe           re          Difference          S.E.
-------------+----------------------------------------------------------------
       lnepc |    1.788449     .4370955        1.351353        .3056724
        eimp |   -.0244251    -.0115132       -.0129119        .0006199
        lnps |    -.072099     .5340157       -.6061147        .1184124
        lnrq |   -1.487755    -1.359142       -.1286132               .
          mr |   -.0956163     .0452498       -.1408662               .
         fdi |   -.0928882     -.016449       -.0764391               .
       lniva |    .9786788     3.569527       -2.590848        .3010853
     lnrdexp |   -.8393148     .1334481       -.9727629               .
     lnresrd |    .5030662    -.1912029        .6942692               .
        lnsi |   -.6191938    -1.294381        .6751876        1.225686
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from xtreg
            B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(10) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                           =      105.38
                Prob>chi2 =      0.0000
                (V_b-V_B is not positive definite)
```

Table G-6: Summary of Fixed Effects model results for BRICS

Variable	fe
lnepc	1.7884488***
eimp	-.02442514***
lnps	-.07209897
lnrq	-1.4877549***
mr	-.09561633
fdi	-.09288815**
lniva	.97867885*
lnrdexp	-.83931484***
lnresrd	.50306623*
lnsi	-.6191938
_cons	-12.29396***

legend: * p<.05; ** p<.01; *** p<.001

Table G-7: Hausman test result for OECD countries

```
.
. hausman FE RE
```

	Coefficients (b) FE	(B) RE	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
lnepc	1.115525	-.2351106	1.350636	.4683077
eimp	-.0190775	-.0075632	-.0115142	.0023695
lnps	-.2242152	.2548699	-.4790851	.1280666
lnrq	1.268979	-2.396989	3.665967	.5481836
mr	-.0959168	-.0134644	-.0824525	.
fdi	-.074381	.0347287	-.1091098	.
lniva	.3412824	2.652371	-2.311089	.
lnrdexp	-.9935755	-.3724171	-.6211585	.
lnresrd	.9308841	.3586067	.5722774	.2137836
lnsi	-4.412998	2.117773	-6.530771	4.757669

```
                          b = consistent under Ho and Ha; obtained from xtreg
           B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(10) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                           =      156.03
                Prob>chi2 =      0.0000
                (V_b-V_B is not positive definite)
```

Table G-8: Summary of Fixed Effects model results for OECD

Variable	FE
lnepc	1.115525*
eimp	-.01907747***
lnps	-.22421519
lnrq	1.2689787
mr	-.09591685
fdi	-.07438103**
lniva	.34128237
lnrdexp	-.99357554***
lnresrd	.93088411***
lnsi	-4.4129982
_cons	-11.580465

legend: * p<.05; ** p<.01; *** p<.001

Heteroskedasticity test

Table H-1: Heteroskedasticity test for All countries group

```
Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (21)  =    2800.87
Prob>chi2 =      0.0000
```

Table H-2: Heteroskedasticity test for LDCs & Others group

```
Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (10)  =    1300.34
Prob>chi2 =      0.0000
```

Table H-3: Heteroskedasticity test for BRICS country group

```
Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (5)  =       14.15
Prob>chi2 =      0.0147
```

Table H-4: Heteroskedasticity test for OECD countries group

```
Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (6)  =       70.05
Prob>chi2 =      0.0000
```

Abstract in Korean (국문 초록)

콩고민주공화국(DRC)의 구리생산과 경제성장, 그리고 에너지 사용량 간의 장기균형관계에 대한 두 개의 연구

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1960 년 독립 이후, 광업부문은 콩고민주공화국의 주요 성장엔진 역할을 해왔다. 광업부문은 수출액의 3 분의 2와 GDP의 25 % (세계 은행, 2004)를 차지한다. 독립 이전부터 지금까지 광산 활동은 국가의 주요 산업 활동이다. 특히 구리는 콩고민주공화국의 가장 중요한 광물로서, 국가의 경제성장에 중요한 역할을 할 것이라고 여겨져 왔다. 그럼에도 구리생산이 콩고민주공화국의 경제발전에 미치는 효과에 및 이를 통한 국가자원정책에 대한 연구는 거의 전무한 실정이다. 또한 수익의 적정 사용 문제, 광업부문의 거버넌스의 구조와 경제성장간의 관계 등이 연구되고 있지 않다. 이에, 본 논문에서는 콩고민주공화국의 주요 거시 및 에너지자원 변수들을 활용한 2개의 장기균형 분석 연구를 통하여 이들을 연구해보고자 한다.

이 논문은 두 부분으로 나누어 져 있다. 첫 번째 부분은 국내 총생산 (GDP), 에너지 소비, 구리 생산과 콩고민주공화국(DRC)이 구리를 수출하는 국제 시장에서 구리가격을 활용, 이들 간의 장기적 균형관계를 조사합니다. 1970~2010년 기간 동안의 연간시계열을 이용 하였다. 이러한 변수 간의 장기적 관계를 조사 하기 위하여 장기 및 단기를 모두 조사할 수 있는 공적분 모형인 벡터자기회귀모형(VAR)을 사용 하였다. 데이터의 시계열 특성을 분석하였고 첫 번째 차이점와 벡터 자기 회귀 모형은 그들 사이에 인과 관계의 방향을 평가하는 데 사용되었다. 연구결과, 주요 변수들 간의 장기균형이 아직 형성되지 않았으나, 단기균형은 존재하였다. 그 외에도, 주요 결과로는 GDP와 에너지 소비

사이의 양방향 인과 관계, GDP에서 구리 생산 으로의 단방향 인과 관계, 구리 생산에서 에너지 소비로의 단방향 인과 관계, 구리 가격과 구리 생산 사이의 양방향 인과관계 등이다.

정책의 관점에서, 경제 성장과 에너지 소비 간의 피드백 가설의 확인에 동반하는 정책은 잘못하면 이들은 경제 성장에 악영향을 초래할 수 있으므로, 에너지 소비를 제한하는 방향으로의 정책 수단의 사용에 대해 주의하여야 한다. 이는 콩고민주공화국의 전화율이 단11 %에 불과하며 광업부문의 생산 증가로 많은 에너지소비가 증가하기 때문이기도 하다. 이보다는 전력산업을 보다 효율적으로 만드는 등 정책의 중점을 주로 공급 측면의 자원개발 옵션 및 에너지 효율성 향상을 통한 에너지 수입 국가의 의존도를 줄이는 데 맞추어야 한다.

본 연구의 두 번째 부분은 1991년부터 2010년까지의 20 년 동안의 구리생산 관련21개국의 자료에 대한 패널 분석을 통하여 국제 구리 시장에서 각 국가의 구리 생산의 시장 점유율 증가에 대한 요인을 조사하였다. Fixed 및 Random효과모형 분석을 통하여 거버넌스, 사회경제적 변수 및 국가별 요인 등의 3개 분류로 나눈 요인변수들을 분석하였다. 주요 결과로, 에너지 소비량 및 정치적 안정과 정부 효율성 및 광물의 가치(rent) 와 같은 변수는 시장 점유율 증가에 긍정적인 변수들로 나타났다. 따라서 이들 변수들을 이한 정책이 국제시장에서의 점유율 증가 및 경제 성장을 위한 조건임을 확인하였다. 에너지 수입, 외국인 직접 투자 (순유입)와 같은 변수는 물론 산업의 부가가치 및 투자자 보호 지수 강도 등은 통계적으로 유의하지 않았다.

정책의 측면에서 거버넌스가 시장 점유율 증가에 중요한 역할을 한다는 결과에 방점을 둔다. 앞으로 기술개발, 저축, 사업성과, 정부효율성, 정책 결정 및 구현 용량 등의 성공적인 결합을 찾아서 정책에 활용하여야 할 것이다. 또한 비즈니스 환경과 성장을 촉진하는 공공 기관을 만들 필요 연계를 구축하는 것을 개인적인 경험을 통하여 정책으로 추천한다. 이러한 일련의 조처들을 통하여 콩고민주공화국 정부의 개혁 역량강화 및 규제 제도를 정비하여 정부정책의 투명성과 책임성 확보에 집중해야

할 것이다.

주요어: 경제성장, 구리생산량, 공적분, 자원 및 에너지 정책, 시장 점유율, 콩고민주공화국 (DR Congo).

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학번: 2010-30816

Abstract in French (불어 초록)

Deux essais sur la relation a long terme entre la production de cuivre, la croissance économique et la consommation d'énergie: Cas de la République Démocratique du Congo (RDC)

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Le secteur minier a été le moteur principal de l'économie de la République Démocratique du Congo (désormais RDC) depuis son indépendance en 1960. Ce secteur produisait les 2/3 des exportations et 25% du Produit Intérieur Brut (désormais PIB ; World Bank, 2004). Malheureusement, les revenues et autres bénéfices générés par le secteur n'ont pas été utilisés dans une perspective de développement durable en grande partie à cause de dysfonctionnements de gouvernance. Malgré tout, les activités minières restent la principale activité industrielle du pays a l'heure actuelle.

Cette thèse se divise en deux parties. La première partie est une recherche pour la RDC sur les relations dans le long terme qu'entretiennent entre eux la croissance économique, calculé en PIB, la production de cuivre, la consommation energetique et le prix du cuivre sur le marché international. Pour ce faire, nous avons utilisé les séries temporelles de 1970 jusqu'à 2010. Pendant la recherche des liens sur le long-terme entre toutes ces variables, nous sommes arrivés à la conclusion, grâce notamment à une approche de co-intégration, a la non-relation dans le long terme mais de l'existence d'une relation a court terme entre elles. Nous avons analysé dans un premier temps les propriétés de données des séries temporelles puis via le modèle Vectoriel Autorégressive avec la première différentielle, nous avons évalué la direction de la causalité parmi ces variables. Il est apparu :
- une causalité bidirectionnelle entre le PIB et la consommation d'énergie ;
- une causalité unidirectionnelle partant du PIB à la production de cuivre ;
- une causalité unidirectionnelle partant de la production de cuivre à la consommation d'énergie ;
- une causalité bidirectionnelle entre la production et le prix du cuivre sur le marché international.

Du point de vue de politique, la confirmation de l'hypothèse de rétroaction entre la croissance économique et la consommation d'énergie, met

en garde contre l'utilisation des instruments des politiques visant à restreindre la consommation d'énergie, dans la mesure où elles peuvent produire l'effet inverse sur la croissance économique. Etant donné que le taux d'électrification national en RDC est d'environ (onze) 11%, il ne semble pas envisageable de réduire la consommation d'énergie. Aussi, il est nécessaire de rendre le réseau électrique plus performant en mettant l'accent principalement sur la réduction des pertes dues au transport et la distribution de l'électricité afin d'augmenter le taux de desserte.

La causalité unidirectionnelle partant de la production de cuivre à la consommation d'énergie s'expliquerait par la grande croissance observée dans le secteur minier de la RDC depuis une décennie grâce à l'afflux massif de capitaux privés à travers le partenariat public-privé (PPP) et, cela est dû à l'application du nouveau code minier en vigueur depuis 2002. Pour un meilleur développement du secteur, les politiques gouvernementales devraient se concentrer sur le renforcement des institutions a travers le renforcement de capacités, efficacité dans la supervision, le contrôle et la surveillance afin d'assurer la transparence dans le secteur minier.
La RDC étant fortement dépendante des importations de produits pétroliers pour ses besoins nationaux. Afin de renforcer la sécurité d'approvisionnement, et faire face à la demande croissante de l'énergie, les politiques énergétiques du gouvernement devraient se concentrer à réduire sa dépendance des énergies importées en donnant la priorité au développement des sources énergétiques domestiques pour un développement et une croissance durables.

Dans la seconde partie de la thèse, nous avons étudié l'effectivité des déterminants pour l'augmentation de part de marché de cuivre de chaque pays producteur, au niveau du marché international. Nous nous sommes basé sur l'analyse des données d'un panel constitué de 21 pays sur 20 ans, en l'occurrence de 1991 à 2010. Nous avons appliqué et estimé le modèle à effets fixes et le modèle à effets aléatoires. Le modèle à effets fixe a été choisi. Les déterminants ont fait ressortir les facteurs relatifs à la gouvernance, à la socioéconomie et la spécificité de chaque pays. Les variables telles la consommation d'énergie, la stabilité politique et l'efficacité des gouvernements, ainsi que les rentes minières se sont avérées être des déterminants positivement significatifs dans l'augmentation des parts de marché. Par conséquent, seules les institutions avec une politique forte et stable peuvent prétendre à une augmentation des parts de marché et donc d'une croissance économique. Les autres variables telles les énergies importées, les investissements directs venant de l'étranger (les entrées nettes), les valeurs ajoutées industrielles et la capacité d'indexation à protéger les investisseurs ne sont pas statistiquement pertinents.

La gouvernance joue politiquement un rôle crucial dans l'augmentation des parts de marché. Il faut donc privilégier et promouvoir le développement de liens étroits entre plusieurs facteurs entre eux, à savoir, les compétences, l'épargne, les performances en affaires, l'effectivité gouvernementale, une bonne réglementation et sa capacité d'implémentation. Cela implique l'élaboration en amont d'un réseau qui requiert lui-même la création d'un environnement propice aux affaires et des secteurs institutionnels qui promeuvent la croissance.

Les réformes politiques du gouvernement devront s'intéresser davantage à consolider les institutions régulatrices à travers le renforcement de capacité et une remise en question sur la transparence et les responsabilités générales et individuelles.

Mot clés : Croissance économique, Production de cuivre, Cointégration, Politiques minière et énergétique, Institutions, Part de marché, RDC.

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&&&&&