The Mineral Depletion-Fuel Imports Nexus and Its Effects on Life Expectancy in Fiji

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ABSTRACT

This paper investigates the nexus between mineral depletion and fuel imports and its possible consequence on life expectancy in Fiji. The first part of the analysis identifies fuel imports as the third type of demand for mineral depletion, apart from domestic and overseas demands. This is based on the fact that with no fossil fuel sources, Fiji has to import fuel as a major energy source. The analysis further investigates such nexus's consequence on life expectancy. Econometric estimators including two-stage least squares (TSLS) are employed in this study.

Key words: *mineral depletion, energy consumption, fuel imports, carbon dioxide emissions, life expectancy, instrumental variables*

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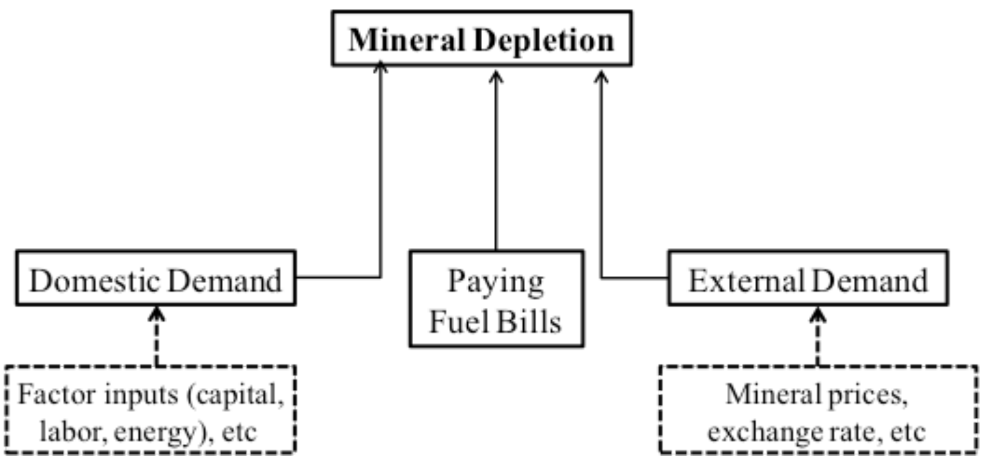
1. INTRODUCTION

Since ancient times mankind has always resorted to elements beneath the ground to use for making shelter, for adornment and ceremonial purposes, or to make tools. While some demand for mineral resources exits domestically, international demand provides the major market for rarer material. Moreover, rising demand for energy, particularly in the non-oil producing countries, has resulted in an increased rate of mineral resources depletion as a means to meet fuel import bills.

The recent boom in mineral exports and prices has generated billions of dollars of extra revenues for governments of resource-rich countries, and global demand for minerals is expected to grow significantly in the coming decades. Clearly, the mining industry offers great potential to developing economies, but achieving this potential requires policy mechanisms which allow transforming mineral wealth into sustainable economic growth. However, the economic performance of mineral rich economies varies significantly. Many countries with rich natural resources do not always enjoy economic and social development success through mineral depletion. Furthermore, traded globally but produced in intense local mining areas, mineral extraction may result in negative economic and environmental impacts. For instance, Coxhead and Jayasuriya (2010) argue that mineral extraction and production have huge environmental and economic consequences, particularly in the absence of strong national institutions.

In the context of small Island developing economies with scarce fossil fuel sources, three types of demand are likely to contribute to the depletion of mineral resources, namely domestic market demand, demand from the international market, and demand for financing fuel import bills.[1] Each of these demands is likely to be further influenced by some other factors. For example, domestic demand can be explained by factor inputs such as capital, labour and energy; external demand is influenced by exchange rate, mineral output, etc; and fuel imports are likely to be influenced by factors such as GDP, world fuel price and exchange rate (see Figure 1).

Figure 1: *Framework of Modelling Mineral Depletion in Fiji*



In this context, this paper examines the mineral resource depletion in Fiji. Economic growth in Fiji has generally been sluggish in the past decade (Prasad, 2010). The mining and quarrying industry is vital to Fiji because of its noteworthy contribution towards government revenue and export earnings. Fiji has small but rich mineral resources of gold, silver and mineral water, which rank among Fiji's top industries. Among minerals and metals in Fiji, gold is the main focus of mineral depletion, and it ranks as the second largest export earner. Production in the mining and quarrying industry has generally been on the rise over the past two decades (see Figure 2).

Concurrently, energy plays a vital role in achieving sustainable development in Fiji. It is a fundamental input for most economic and social activities and a prerequisite for development in other sectors such as education, health, and communication. Consistent with economic development, both energy production and consumption have continued to rise over the past two decades in Fiji. Fossil fuel is the main source of energy production. In 2006, around 43 percent of energy capacity came from hydropower, while 57 percent came from diesel generation. Given that Fiji is a country with no oil resources, a continued rise in fossil fuel imports together with soaring global oil prices, creates a significant deficit in trade balance. Financing fossil fuel imports bills relies on foreign reserves from other sectors such as exports, remittances and tourism. There is a clear connection between mineral resource extraction and energy consumption in Fiji (see Figure 3).

The particular focus of this study is to identify the factors determining mineral resource depletion in Fiji. Using the demand context, this study will explore mineral resource depletion with respect to internal demand, external demand and more importantly demand for financing fuel import bill. Moreover, this paper further investigates the effect of mineral depletion activity on life expectancy in Fiji through increasing pollution. The effect of pollution on health and hence life expectancy is well established in Kampa and Castanas (2008) and Neuberg, Rabczenko and Moshammer (2007) who confirm that short- and long-term exposure to a number of air pollutants, even at relatively low levels, are linked to premature mortality and reduced life expectancy. This paper will make an important contribution to the literature on modelling the nexus between natural resource depletion and fuel imports and its influence on life expectancy in energy scarce countries.

The rest of the paper is organised as follows: section 2 provides a discussion of the relevant existing literature. In section 3, two systems of equations are set up to respectively investigate the mineral depletion and fuel imports nexus and its influence on life expectancy in Fiji. This is followed by section 4 where empirical findings are discussed. Section 5 draws on conclusions and policy implications.

2. THE LITERATURE

Over the last few decades, researchers have attempted to explain respectively natural resource depletion (e.g. Tilton, 1989), fuel usage (e.g. Sadorsky, 2011). Efforts have also been made to examine the relationship between resource depletion and economic development. For instance, Pegg (2006) claims the reality of mineral-led development has not lived up to its rhetorical promise that mining can contribute to poverty alleviation. Schilling and Chiang (2011) suggest that a continued depletion is unlikely to lead to a collapse of economic development, and the use of resources due to relatively cheaper renewable energies more or less will smoothly shift towards a sustainable economic development.

Similarly, a huge literature exists on the impacts of fuel or energy on economic development, demonstrating solid theoretical and practical background for one to investigate the correlation between the two. For instance, Dunkerley and Ramsay (1982) argue that higher prices of imported fuels contributed to accelerate inflation and to lower economic growth. Narayan and Singh (2007) find that electricity consumption, employment and GDP are cointegrated in Fiji. Similar analysis based on cointegration tests can be seen in a variety of studies such as Erdal et al. (2008), Odhiambo (2009), Apergis and Payne (2011), and Gurgul and Lach (2012). The cointegration technique also enables researchers to study causality between energy consumption, CO2 emissions and economic growth in recent years. This can be seen in a number of papers such as Apergis and Payne (2009), Chang (2010), De Freitas and Kaneko (2011) and Ghosh (2010).

However, there is lack of literature on the impact of demand for fossil fuel on non-fossil mineral resources in fuel importing countries with limited export base, particularly in small island countries. With the presumption that rising energy demand, together with soaring fuel prices is likely to increase extraction of non-fuel mineral in oil importing countries as a means of offsetting fuel import bills, this study attempts to fill the gap that exists in the current literature.

3. THE MODEL AND DATA

3.1 THE MINERAL DEPLETION-FUEL IMPORTS NEXUS

Domestic demand, external demand and energy consumption are expected to have positive coefficients in the model of explaining mineral depletion in Fiji. An increase in domestic demand will increase the depletion of mineral resources given that an increase in national income will increase infrastructure development and hence more mineral resources will be extracted. Similarly, increase in international demand for mineral resources will increase depletion of domestic mineral resources. Likewise, rising fuel import bill will create demand for mineral resource depletion. As Fiji does not have many foreign exchange earning sources, more and more mineral resource will be extracted to meet the trade deficit created by rising fuel prices.

In addition, these demands are further likely to be influenced by some factors, including those specified in the system. For example, domestic demand can be explained by factor inputs including energy, capital and labour. External demand is influenced by exchange rate and mineral output, and fuel imports are likely to be affected by world fuel price, exchange rate and domestic demand for energy.[2] This mechanism is structurally demonstrated in Figure 1, and can be summarised in the following simultaneous equations system:

$$(1)\quad \ln(\text{mineral})_t = \beta_0 + \beta_1 \ln(\text{GDP\_m\_ex})_t + \beta_2 \ln(\text{exports})_t + \beta_3 \ln(\text{energy})_t + \beta_1 \text{instability}_t + e_t$$

where

$$\ln(\text{GDP\_m\_ex})_t = \alpha_0 + \alpha_1 \ln(K)_t + \alpha_2 \ln(\text{L})_t + \alpha_3 \ln(\text{energy})_t + u_t$$

$$\ln(\text{exports})_t = \gamma_0 + \gamma_1 \ln(\text{mineral})_{t-1} + \gamma_2 \ln(\text{exchange rate})_t + \gamma_3 \ln(\text{rural})_t + v_t$$

In the above system, *mineral* represents the output of the mining and quarrying industry (at 2005 prices, US dollars); *GDP_m_ex* represents the domestic demand, measured by GDP less mining and quarrying industrial output and less export (at 2005 prices, US dollars);[3] *exports* captures the external demand (at 2005 prices, US dollars);[4] *energy* is energy consumption (million kilowatts hours); *K* and *L* are capital stock and labour force;[5] *exchange rate* is Fiji dollars per US dollar; *rural* is rural population. It is taken as the inverse measure of urbaniation; and *instability* is a dummy variable. It captures several natural disasters in 1970s and 1980s, coups in 1987, 2000 and 2006, and land lease policy change in 1997.

3.2 MINERAL DEPLETION'S IMPACTS ON LIFE EXPECTANCY

Apart from explaining mineral depletion in Fiji, this paper also tries to identify the impact of mining activities on Fiji's economic growth and social development. In the first part of this study, we used domestic demand as an explanatory variable in order to ascertain whether mineral depletion in Fiji is for domestic economic development. It would be of the same interest to find out (i) whether mineral depletion contributes importantly to the Fijian economy, and if yes (ii) whether gain in economic development contributes to the Fijian society in terms of environmental maintenance and human capital development. To address the above questions, we will further investigate the following system:

$$(2)\quad \ln(\text{incpc})_t = \theta_0 + \theta_1 \ln(\text{mineral})_t + \theta_2 \ln(\text{kpc})_t + \theta_3 \text{instability}_t + \theta_4 \ln(\text{incpc})_{t-1} + \varepsilon_t$$

$$(3)\quad \ln(\text{CO2})_t = \vartheta_0 + \vartheta_1 \ln(\text{incpc})_t + \vartheta_2 \ln(\text{CO2})_{t-1} + \varphi_t$$

$$(4)\quad \ln(\text{lifeexp})_t = \delta_0 + \delta_1 \ln(\text{incpc})_t + \delta_2 \ln(\text{CO2})_t + \omega_t$$

where *incpc* is income per capita (at 2005 prices, US dollars); *kpc* is capital per capita (at 2005 prices, US dollars). Capital stock is calculated based on the perpetual inventory method using gross fixed capital formation, and a depreciation rate of 6 percent; *CO2* represents carbon dioxide emissions, measured in metric tons per capita; and *lifeexp* is life expectancy at birth, measured in years. It is a proxy for human capital in this paper; and *mineral* and *instability* are the same as defined in section 3.1.

In the above system, Equation (2) is set up to investigate the contribution of the mining industry to per capita income. Mining is expected to have a positive sign as mining activity contributes to economic activity and income. Equation (3) assesses CO2 emissions to identify main contributors to the deterioration of the environment. We presume that mining activity is likely to contribute to CO2 emissions and hence will have negative impact on the environment. Equation (4) tries to identify whether improvement in per capita income helps to enhance human capital in Fiji. We presume that increase in income per capita will improve life expectancy, while CO2 is expected to have a negative impact on life expectancy.

3.3 DATA

Dataset required for the first part of the current analysis, which tries to explain mineral depletion, covers the period 1970-2006. The second part which tries to assess mineral depletion's impact on life expectancy covers the period 1980-2006. A sample size of 37 for the first part is reasonably large for time-series analysis, while sample size of 27 for the second part is relatively small. Therefore, estimates in the second part may not be robust enough in terms of magnitudes of effect. However, they should be indicative enough to illustrate the story behind phenomena since estimates should have correct signs.

Apart from world fuel prices, which are collected from IMF database and CO2, and life expectancy from World Bank database, the rest series are obtained from the Fiji Bureau of Statistics. Table 1 summarises sample statistics of some variables mentioned in the above. Figure 2 presents time trends of variables under consideration. Figure 3 presents scatter diagrams between pair-wise variables. The first diagram in Figure 3 demonstrates more or less clear positive correlations between mineral depletion and three types of demand, namely domestic demand (represented by 'GDP-Mineral-Exports'), external demand ('exports') and demand for financing fuel imports exports ('energy consumption'). The second diagram in Figure 3 demonstrates clear positive correlations, though with some outliers, between mineral and income per person, income per person and CO2 per person, as well as CO2 per person and life expectancy at birth, respectively.

Table 1: *Basic Description of Variables, Fiji*

Variable	Mean	Standard Deviation	Min. Value	Max. Value
1970-2006				
ln(mining) (constant 2000 US$)	15.22	.20	14.84	15.68
ln(GDP less mining) (constant 2000 US$)	16.92	.19	16.58	17.29
Exports relative to GDP (%)	.51	.07	.37	.65
ln(energy consumption) (million kilowatts hours)	5.61	1.12	3.13	6.73
ln(world fossil fuel price) (constant 2000 US$)	-.94	.50	-1.85	.14
ln(exchange rate) (Fiji dollars per US$)	.25	.33	-.23	.82
1980-2007				
Income per person (PPP US$)	3886.89	441.92	3238.37	4716.7
CO2 per person (metric tons)	1.21	.42	.66	2.30
Life expectancy at birth (years)	71.21	4.03	64.24	75.21

Figure 2: *Trends of Time Series in Fiji over 1970-2010*

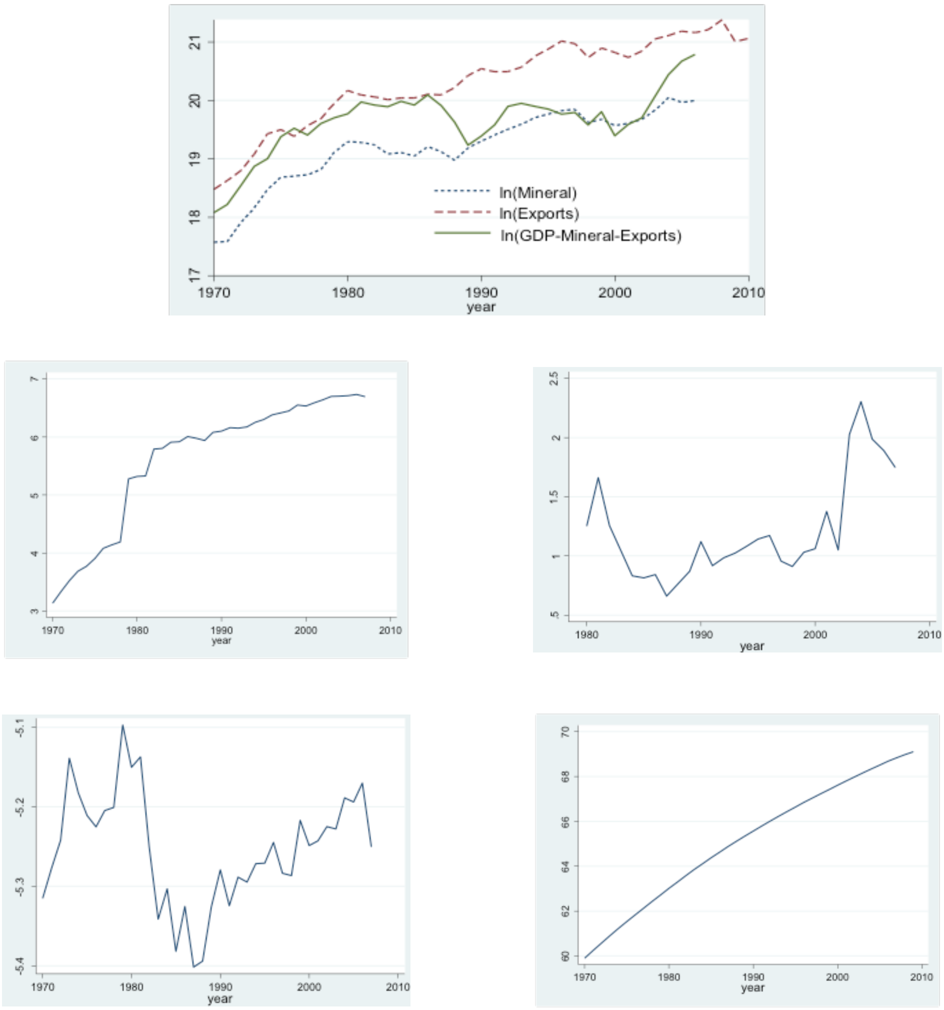
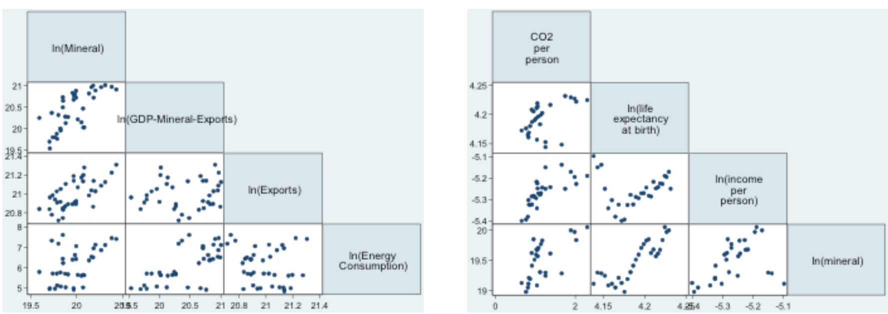


Figure 3: *Scatter Plots between Time Series in Fiji over 1970-2006*



4. EMPIRICAL RESULTS

4.1 UNIT ROOT AND BOUNDS COINTEGRATION TESTS

Before proceeding to estimate various models, all variables are tested for stationarity. Based on augmented Dickey-Fuller unit root test and Phillips-Perron unit root test with the null hypothesis of variable under test being non-stationary, all variables are found to be integrated of order one based on findings that (1) τ-statistics are less than corresponding 5% critical values for all variables at level and thus the null is not rejected; and (2) τ-statistics are greater than corresponding 5% critical values for all variables in first difference and thus the null is rejected.[6]

Before finalising the determinants of mineral depletion, we proceed to examine whether there exists long-run relationship(s) between variables under investigation. Based on Bounds cointegration tests,[7] three cointegrating relationships are identified for mining and quarrying output, external demand and internal demand. For the interest of the current study, we only focus on the relationship between mineral depletion and regressors discussed in the above context. The causality problem will be taken care of by means of the two-stage least squares (TSLS) estimator, which will be discussed below.

4.2 REGRESSION OUTPUT: PART (I)

To investigate the hypotheses discussed in the above context, the OLS estimator is initially employed. OLS estimation of Eq(1) suffers from autocorrelation in the error term. To overcome this, an autoregressive model is adopted by including a lagged dependent variable in Eq(1).

The diagnostic statistics in Table 2 show that the OLS regression was free from problems such as multicollinearity, heteroskedasticity, non-normality of the error, and incorrect functional form of the model. However, autocorrelation in the error was identified in column (1). Inclusion of the lagged dependent in the right-hand side of the model successfully removed this problem. See columns (2)-(4).

Table 2: Regressions on $\ln(\text{mineral})_t$

ESTIMATION METHOD	(1) OLS	(2) AR-OLS	(3) TSLS	(4) GMM
VARIABLE	COEF. [*t*-stat]	COEF. [*t*-stat]	COEF. [*t*-stat]	COEF. [*t*-stat]
Constant	-1.939[-1.10]	-3.189[-2.20] **	-3.484[-1.81] *	-2.464[-1.50]
$\ln(\text{mineral})_{t-1}$		0.408[4.92] ***	0.402[3.64] ***	0.424[4.38] ***
$\ln(\text{exports})_t$	0.812[9.15] ***	0.568[6.61] ***	0.595[4.11] ***	0.551[3.93] ***
$\ln(\text{GDP-mineral-exports})_t$	0.221[5.23] ***	0.138[3.77] **	0.130[2.07] **	0.102[1.68] *
$\ln(\text{energy consumption})_t$	0.062[2.90] ***	0.043[2.53] ***	0.048[1.98] **	0.054[2.37] **
Instability	-0.046[-1.64]	-0.093[-3.96] ***	-0.091[-3.36] ***	-0.082[-3.65] ***
Sample size	37	36	36	36
Adjusted R-squared	0.8602	0.9181	0.9177	0.9141
Root mean squared error	0.0755	0.0580	0.0581	0.0542
Diagnostic tests				
Variance inflation factor (mean)	1.75	2.71	2.71	2.71
Durbin-Watson statistic	1.136	2.291	2.259	2.177
Durbin's *h* statistic	-	-1.007	-1.037	-0.653
Breusch-Godfrey LM test: chi^2 (*p*-value)	6.60 (0.0102)	1.25 (0.2645)	-	-
Breusch-Pagan/Cook-Weisberg test: chi^2 (*p*-value)	1.68 (0.1952)	0.96 (0.3271)	-	-
Ramsey RESET test: F-stat (*p*-value)	1.37 (0.2698)	0.55 (0.6503)	-	-
Jarque-Bera normality test: chi^2 (*p*-value)	1.029 (0.5979)	0.2658 (0.8755)	-	-

Exogeneity test [Durbin-Wu-Hausman *chi-sq* statistic (*p*-value)]	
$\ln(\text{mineral})_{t-1}$	2.70 (0.100)
$\ln(\text{exports})_t$	3.62 (0.057)
$\ln(\text{GDP-mineral-exports})_t$	22.56 (0.00)
$\ln(\text{energy consumption})_t$	0.53 (0.465)

Notes:

1. In the diagnostic tests, Variance inflation factor (VIF) is used to test for multicollinearity. A variable whose VIF value is greater than 10 could be considered as a linear combination of other independent variables. Mean VIF values are reported in the table. Durbin-Watson test is used to test for the first-order autocorrelation, Durbin's *h* statistic whose value is calculated based on Durbin-Watson statistic is useful to test for autocorrelation in the autoregressive models such as those in columns (2)-(4), and Breusch-Godfrey LM test (H_0: no autocorrelation in the error) is also to test for autocorrelation. Breusch-Pagan/Cook-Weisberg test (H_0: errors are homoskedastic) is to test for heteroskedasticity. Ramsey RESET test (H_0: the specification has a correct functional form) is to identify the specified model which does not omit relevant variables nor include irrelevant variables. Jarque-Bera normality test (H_0: the error has a normal distribution) is to check whether regression error follows a normal distribution. Endogeneity of explanatory variables is checked by the Durbin-Wu-Hausman test (H_0: regressor is exogenous). The null hypothesis will be rejected upon the *p*-value less than, say, the 5% significance level.
2. The Diagnostic tests indicate the presence of autocorrelation in the OLS regression in column (1). The autocorrelation problem is solved by including the lagged dependent variable. See columns (2)-(4). To control for the endogeneity problem of $\ln(\text{exports})_t$ and $\ln(\text{GDP-mineral-exports})_t$, which is identified from the Durbin-Wu-Hausman exogeneity test, the TSLS and GMM estimators are employed. See columns (3) and (4). Empirical results are better off without controlling for the weak exogeneity of $\ln(\text{mineral})_{t-1}$.
3. The first-stage OLS regression outputs for the endogenous $\ln(\text{exports})_t$ and $\ln(\text{GDP-mineral-exports})_t$ are reported in the lower panel of the table, where the validity of instrumental variables is evidenced.
4. *t*-statistics are in square parentheses. *p*-values are in round parentheses.
5. * Significant at 10% significance level. ** Significant at 5% significance level. *** Significant at 1% significance level.

Yet, inclusion of $\ln(\text{mineral})_{t-1}$ might impose the endogeneity problem. However, 'with regard to the current values of the endogenous variables, they may be regarded as having already been determined. The deciding factor is whether or not they are uncorrelated with the current disturbances, which we might assume' (Greene, 2000, p.655). According to the original model, $\ln(\text{mineral})_t = \alpha_0 + v_t$,[8] which suffers from the residual autocorrelation problem, the lagged dependent variable $\ln(\text{mineral})_{t-1}$ in the autoregressive model $\ln(\text{mineral})_t = \alpha_0 + \alpha_1 \ln(\text{mineral})_{t-1} + v_t$ would be correlated with the error v_t.[9]

Besides $\ln(\text{mineral})_{t-1}$, some other regressors in the model might also be endogenous, which seems to be evidenced by the generally high *t*-statistics in columns (1) and (2), particularly those on $\ln(\text{GDP\_m\_ex})_t$ and $\ln(\text{exports})_t$. The Durbin-Wu-Hausman test is thus conducted to formally test for the exogeneity of regressors. The *Chi-square* statistics are 2.70, 3.62, 22.56 and 0.53 for $\ln(\text{mineral})_{t-1}$, $\ln(\text{exports})_t$, $\ln(\text{GDP\_m\_ex})_t$ and $\ln(\text{energy})_t$, respectively (see Table 2). The null hypothesis of exogeneity is not rejected for $\ln(\text{energy})_t$, while it is rejected at the 1% significance level for $\ln(\text{GDP\_m\_ex})_t$ and marginally at the 5% significance level for ln(exports). The $\ln(\text{mineral})_{t-1}$ is found to be weak exogenous, since the probability of accepting the null of exogeneity is 0.100 based on the Durbin-Wu-Hausman test. The TSLS estimator was therefore adopted to correct the endogeneity problem. Instrumental variables (IVs) for the problematic $\ln(\text{GDP\_m\_ex})_t$ include ln(energy) and $\ln(\text{GDP})_{t-1}$,[10] and $\ln(\text{mineral})_{t-1}$, $\ln(\text{exchange rate})_t$ and $\ln(\text{rural population})_t$ for the problematic $\ln(\text{exports})_t$.[11] We also tried to control the weak exogeneity of $\ln(\text{mineral})_{t-1}$ by using $\ln(\text{mineral})_{t-2}$ as the IV.[12] However, the TSLS estimator does not support this practice since estimates turned out biased and inefficient. We therefore proceed our analysis without controlling the weak exogeneity of $\ln(\text{mineral})_{t-1}$[13]

The empirical results seem robust since there is no significant difference between the OLS, TSLS and GMM estimates in columns (2)-(4). Yet, the TSLS and GMM estimators do improve the OLS estimates as *t* statistics are reduced to reasonable levels once the endogeneity problem has been controlled for. Given the smaller root mean squared error value in GMM than in TSLS, though the difference is trivial, our discussion on the empirical findings is therefore based on the GMM estimation results shown in column (4) of Table 2.

The performance of the variables under consideration, in terms of signs and magnitudes of the estimates, is found to be within expectation. In general, the analytical results are consistent with our analysis in the above context that, external demand is the biggest contributor to mineral depletion in Fiji followed by domestic demand and then energy consumption. The results are also consistent with the fact that almost all gold extracted in Fiji over the last 4 decades have been exported. Mineral water over the last ten years has become a major export industry for Fiji.

More specifically, a one percent increase in external demand (exports) leads to an increase in mineral depletion by 0.55 percent, keeping other factors unchanged. Similarly, a one percent increase in domestic demand (GDP less mineral output and exports) leads to around 0.10 percent rise in mineral depletion, and a one percent rise in energy consumption leads to 0.05 percent in mining depletion. The empirical result also notes that, keeping other factors unchanged, the dummy variable, *instability*, is found to have a significant but negative impact on mineral depletion in Fiji. The coefficient of -0.08 on *instability* implies that the occurrence of an event, which could be a major natural disaster, coup or policy change, would on average reduce mineral depletion by around 0.077 ($e^{-0.08} - 1$) percent. Fiji, when compared to Mauritius, had similar rates of growth in the 1970s and early 1980s (Prasad & Tisdell, 2006). It has similar rates of national savings and investment with similar social indicators. However, Fiji had its first military coup in 1987, and since then the slide in Fiji's economic performance has continued with two more coups in 2000 and 2006. Potential for further investment in the extraction of gold and cooper have been delayed and reduced due to political instability in Fiji over the last three decades.

The external demand variable proves to be the most highly significant factor, both statistically and quantitatively, in explaining the mining activity in Fiji. This is in line with the situation that mineral (mainly Gold) is the second largest export in Fiji and that the demand for gold from the international market is strong.

The impact of domestic demand on mineral depletion is next to that of external demand, which provides strong evidence that mineral depletion in Fiji is also for domestic development purposes. This finding is consistent with the fact that domestic construction activity creates a demand for domestic minerals, which in this case refers to construction materials such as limestone, sand and gravel.

The performance of the energy consumption variable, which is highly statistically significant but less quantitatively significant, seems to support our presumption that mineral depletion partly contributes to pay fossil fuel import bills.

4.3 REGRESSION OUTPUT: PART (II)

Having identified the significant roles of domestic demand on mineral depletion, we thus continue searching for answers to questions such as 'whether mineral depletion benefits the Fijian economy', and if yes, 'whether economic gain is at the cost of environmental degradation and human capital'. Positive answers to the above questions should be able to provide some evidence for sustainable economic and social development in Fiji.

The estimation procedures for equations (2)–(4) are similar to those discussed in sections 4.1 and 4.2. Equations (2) and (3) are assessed by the OLS estimator, while equation (4) is estimated by the TSLS estimator due to the endogenous regressors $\ln(\text{income per person})_t$ and $\ln(\text{CO2 per person})_t$. Regression results are summarised in Table 3.

Interpretation of regression results presented in this section requires special caution as the estimates may be biased due to an insufficiently large enough sample for each regression in Table 3. Sample size in this section is constrained by the data on CO2, which is only available over the period 1980-2007. We, therefore would regard regression output in Table 3 as only indicative in assessing the effect of mineral depletion on human capital.

Another thing worth noting about regression (4) is that, apart from the two regressors, life expectancy is likely to be influenced by some other human development indicators such as nutrition and sanitation. It, therefore should not be surprising that the model suffers from the autocorrelation problem due to the omission of relevant variables. However, since those indicators are not available, we leave the result as it is. Therefore, regression results should not be regarded as robust, since regression (4) is not exhaustive in explaining the effect of mineral depletion on human capital, as there may be several interactive mechanisms at play influencing life expectancy.

Column (1) in Table 3 sheds light on the statistically significant role of mining activity on per capita income in Fiji. The estimation output suggests that one percent increase in mineral depletion contributes to around 0.14 percent increase in per capita income, given other factors remain unchanged. This provides strong evidence that the activity of mineral depletion in Fiji not only satisfies domestic development demand (evidenced in section 4.2), but in turn makes significant contribution to the Fijian economy.

The findings from the estimation of Equations (3) and (4) shed light on the final answer to the sustainable economic and social development question. In column (2), the estimated partial slope parameter of the income per capita variable indicates that, given other factors are constant, a one percent increase in income per capita deteriorates the environment by increasing carbon dioxide per person by 1.29 percent. This suggests that carbon dioxide per person increases by around 0.4 metric tonnes at every US$1000 increase in per capita income in Fiji.

As expected, per capita income contributes positively to human capital in Fiji by increasing life expectancy by 0.80 percent at every percent increase in per capita income (see column (3)). Deterioration of environment is found to cause harm to human capital by reducing life expectancy by 0.21 percent, which is equivalent to a decline of around 12 years on average in life expectancy upon one metric tonne increase in CO_2 per person, given other factors remain unchanged. The fact is terrifying because gaining 1 tonne of carbon dioxide per person within the past two decades evident in Fiji (see Figure 2).

Table 3: *Mineral Depletion's Impact on Life Expectancy in Fiji*

Column	(1)	(2)	(3)
Equation	(2)	(3)	(4)
DEPENDENT VARIABLE, Y_t	**ln(income per person)$_t$**	**ln(CO2 per person)$_t$**	**ln(life expectancy)$_t$**
ESTIMATION METHOD	OLS	OLS	TSLS
VARIABLE	COEF. [*t*-stat]	COEF. [*t*-stat]	COEF. [*t*-stat]
Constant	-6.410[-2.82] ***	-10.590[-3.36] ***	-2.318[-1.76] *
Y_{t-1}	0.516[3.33] ***	0.513[3.69] ***	
ln(mineral)$_t$	0.135[2.03] **		
ln(capital per worker)$_t$	0.128[2.95] ***		
Instability	-0.027[-1.72] *		
ln(income per person)$_t$		1.29[3.37] ***	0.800[4.99] ***
ln(CO2 per person)$_t$			-0.206[-3.26] ***
Sample size	27	27	27
Adjusted R-squared	0.700	0.724	0.339
Root mean squared error	0.038	0.172	0.046
Diagnostic tests			
Variance inflation factor (mean)	1.15	1.71	2.24
Durbin-Watson statistic	2.258	1.979	0.986
Breusch-Godfrey LM test: chi^2 (*p*-value)	0.96 (0.327)	0.26 (0.608)	-
Breusch-Pagan/Cook-Weisberg test: chi^2 (*p*-value)	0.71 (0.400)	0.99 (0.320)	-
Ramsey RESET test: F-stat (*p*-value)	0.80 (0.512)	0.07 (0.975)	-
Jarque-Bera normality test: chi^2 (*p*-value)	0.40 (0.820)	0.8702 (0.647)	0.7857 (0.675)

Exogeneity test [Durbin-Wu-Hausman *chi-sq* statistic (*p*-value)]	
ln(income per person)$_t$ in column (2)	2.11 (0.15)
ln(income per person)$_t$ in column (3)	25.75 (0.00)
ln(CO2 per person)$_t$ in column (3)	6.06 (0.01)

Notes:

1. Estimation procedure in this second part of analysis is the same as that in Table 2.
2. Y_{t-1} is the lagged dependent variable in the corresponding regression.
3. Sample size for each regression is not large enough, as data for CO2 only covers 1980-2007. The interpretation of the estimates should therefore require special caution because the estimates may be biased. Therefore, we would regard regression output in this table as indicative but not robust.
4. The variables ln(income per person)$_t$ and ln(CO2 per person)$_t$ in Equation (4) are found to be endogenous. The TSLS estimator is therefore employed by using the education index, obtained from the *UN Human Development Index*, and labour force as IVs for the two problematic regressors respectively.
5. Apart from the included two regressors in Equation (4), life expectancy could be explained by some other human development indicators such as nutrition and sanitation. Given the omission of these indicators, one would not be surprised by the presence of autocorrelation in the error. However, due to unavailability of these indicators, we keep the result as it is. Therefore, regression results should not be regarded as robust, since regression (4) is not exhaustive in explaining the effect of mineral depletion on human capital.

5. CONCLUDING REMARKS AND POLICY IMPLICATIONS

To summarise, the empirical analysis finds strong evidence that mineral depletion in Fiji is driven by domestic economic development demand, external demand and the demand to pay for fossil fuel import bills. Besides its capability of meeting domestic demand, the mining and quarrying industry also positively and significantly contributes to promote the country's economic development and reduce poverty. Although the mining activity has economic benefits, it increases carbon emissions and reduces life expectancy in Fiji. Though the empirical findings in the second part of the analysis may not be robust, they are indicative enough to alert us to think seriously about the long-run environmental and social problems.

With the perception of the gain and loss of mineral depletion in Fiji, together with the fact that global demands for minerals and metals are expected to continue rising in the long term, we are therefore left with the question of 'how to develop a sustainable mining system and transform mineral wealth into sustainable economic growth and social development?' Fiji's history of mining extraction has been littered with controversies about benefits to landowners. In fact gold mining activities have always been controversial as distribution of benefits to labour and land owners have always been considered to be low. In addition, environmental impact assessments of undertaking mineral depletion have not been clear, and this has also caused some difficulty in the mining and quarrying sector.

The key to sustainable and viable mining lies in allocating mineral revenues equitably and effectively, developing robust governance frameworks for the extractive industries, and strengthening government administration. A small state like Fiji needs to put in place a detailed national policy on the mining and quarrying industry and how the revenue from mining and quarrying is managed in the domestic economy.

ENDNOTES

1 Similarly Dobozi (1978), argues that domestic economy development creates an increased demand for raw material and fuel. Since some of these will be sourced from the international market, it puts immediate pressure on nations to generate sufficient export revenue to match imports needed.

2 Narayan et al. (2008), based on daily data over 2000-2006, find that a rise in oil prices leads to an appreciation of the Fijian dollar vis-à-vis the US dollar. This shall provide an empirical evidence of an endogeneity problem if one tries to model fuel imports, which however is beyond the scope of the current study.

3 Due to the fact that part of mineral products is exported, mineral depletion and exports series are likely to be integrated. We are faced with the possible consequence of subtracting mineral twice from GDP. Yet, due to no access to disaggregate data on domestically consumed mineral products, and those being exported, we leave the analysis as it is.

4 This is validated by the fact that mineral is the major component of exports, and also due to the reasonably high correlation (with the coefficient of 0.6473) between real exports and real mining output over the period 1970-2006.

5 In the empirical analysis in section 4, *K* and *L* are jointly approximated by *GDP* since *K* is not directly observed.

6 Test results are not reported due to space limitation, but available upon request.

7 Bounds cointegration tests are adopted due to relatively small samples for the current analysis. Long-run relationships are identified upon calculated *F*-statistics being greater than upper bound critical values for corresponding sample observations. Critical values are obtained from Narayan (2005). We use critical Bounds statistics for a sample of 30 (the smallest sample size available in Narayan 2005), for the second part of the current analysis where sample size is 27 this portion seems incomplete/ awkward. Test results are not reported due to space limitation, but available upon request.

8 For the simplicity of demonstration the other explanatory variables are dropped.

9 Due to the autocorrelated residuals (here we assume an autocorrelation of order 1), the original model can be re-written as $\ln(\text{mineral})_t = \alpha_0 + \rho v_{t-1} + u_t$ where u_t is assumed to satisfy classical assumptions. The lagged dependent variable $\ln(\text{mineral})_{t-1}$ is obviously correlated with the error $(\rho v_{t-1} + u_t)$ in the autoregressive model $\ln(\text{mineral})_t = \alpha_0 + \alpha_1 \ln(\text{mineral})_{t-1} + \rho v_{t-1} + u_t$.

10 $\ln(\text{GDP})_{t-1}$ is used as one of the instrumental variables for $\ln(\text{GDP\_m\_ex})_t$. It is an approximate measure to capture factor inputs such as labour force and capital stock, due to a reasonably high correlation, with correlation coefficient of 0.844, between $\ln(\text{GDP\_m\_ex})_t$ and $\ln(\text{GDP})_{t-1}$.

11 The variable $\ln(\text{mineral})_{t-1}$ is included as one of the instrumental variables for ln(exports)

$_t$ because of its importance in Fiji's total exports. The lagged mineral variable is less likely to be correlated with v_t in the specification equation to explain $\ln(\text{exports})_t$. And the Durbin-Wu-Hausman test further confirms the exogeneity of $\ln(\text{mineral})_{t-1}$ in the model of $\ln(\text{exports})_t$ with test statistic $chi^2 = 1.037$ and p-value = 0.308.

[12] The validity of $\ln(\text{mineral})_{t-2}$ as the IV could be seen as follows: Since the autoregressive model $\ln(\text{mineral})_t = \alpha_0 + \alpha_1 \ln(\text{mineral})_{t-1} + w_t$, though suffers from the endogeneity problem, does not have the residual autocorrelation problem, $\ln(\text{mineral})_{t-2}$ in the reduced form $\ln(\text{mineral})_t = \gamma_0 + \gamma_1 \ln(\text{mineral})_{t-2} + (\alpha_1 w_{t-1} + w_t)$ is not correlated with the error term $(\alpha_1 w_{t-1} + w_t)$.

[13] The first-stage OLS regression results, which are only indicative in explaining $\ln(GDP\_m\_ex)_t$ and $\ln(\text{exports})_t$, are available upon request.

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