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Mineral Depletion, Fuel Imports and Development Sustainability in the Energy Scarce Country Fiji over 1970-2006

Hong Chen, Biman Chand Prasad and Baljeet Singh
School of Economics, University of the South Pacific, Fiji

Abstract

This paper investigates the relationship between mineral depletion, energy consumption and development sustainability in Fiji. Apart from domestic and external demands for minerals, energy consumption in Fiji has also been included to represent the third type of demand to explain mineral depletion. This is due to the fact that with no fossil fuel sources, Fiji has to import fuel from overseas to produce energy, which is a vital factor of production. Therefore, in the first part of this analysis we identify the correlation between mineral depletion, domestic demand, external demand and demand for financing fuel import bills. In addition, given the empirical evidence found in the first part of the analysis (that domestic demand is a significant contributor to mineral depletion in Fiji) sustainable development is further investigated by examining environment and human capital's response to economic activities. Econometric estimators such as OLS, TSLS and GMM are applied to the above analysis, and robust findings are evidenced by the consistency of the three estimators.

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

JEL classification: C26 I15 O13 Q32 Q53

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1. Introduction

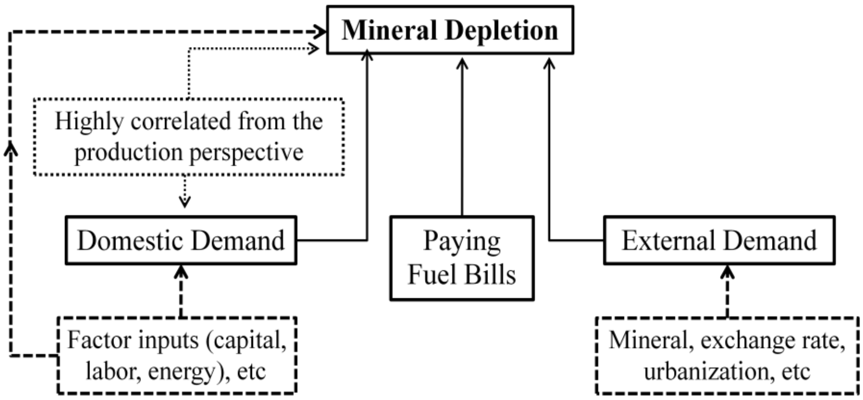
Since ancient times mankind has always resorted to elements underneath the ground to use for making shelter, for adornment and ceremonial purposes, or to make tools. While some of the demand for mineral resources exits domestically, international demand provides the major market for rarer material. Moreover, rising demand for energy, particularly in the non-oil producing countries, have 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 development and environmental impacts. For instance, Coxhead and Jayasuriya (2010) argue that mineral extraction and production has 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 originating from the international market, and demand for financing fuel import bills. Dobozi (1978) argued that domestic economy development creates an increased demand for raw material and fuel and some of these will be sourced from the international market. This puts immediate pressure on the nations to generate sufficient export revenue to match imports needed. Similar sentiment is also shared by Stevens (1993) who argued that developing countries may over exploit raw materials such as fisheries and forestry to generate increased export revenue, particularly in the presence of market failure.

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, labor 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. Fiji is one of the larger economies in the small Pacific Islands region. Economic growth in Fiji has generally been sluggish in the past decade (Prasad, 2010). Average rates of real GDP growth have been around 2 percent in the last two decades. 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 second largest export earner. Production in the mining and quarrying industry has generally been on the rise over the past two decades (see Figure A1 in Appendix).

Concurrently, energy plays a vital role in achieving sustainable development in Fiji. It

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is a fundamental input to most economic and social activity and a prerequisite for development in other sectors such as education, health, and communications. 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. This, together with the fact that hydropower has a very limited capacity to develop, provides a strong support for us to use energy consumption to approximate fuel imports whose data is not consistently available. And one should be cautious about using this proxy because apart from generating electricity, fuel is also used in the transportation sector. However, a reasonably high correlation (with coefficient of 0.72) between energy consumption and carbon dioxide emissions in Fiji over the last three decades to a great extent validates our use of this proxy.

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 clear connection between mineral resource extraction and energy consumption in Fiji, see Figure A2 in Appendix.

The particular focus of this study is to identify the factors determining the 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 channels through which mining affects the nation in terms of economic and social sustainability. This paper will make an important contribution to the literature on modelling the relationship between depletion of natural resources, fuel imports and sustainable development in energy scarce countries.

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The rest of the paper is organized 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 mineral depletion and development sustainability to seek answers to the questions proposed in the above. This is followed by section 4 where empirical findings are discussed. Section 5 draws the conclusions and policy implications.

2. The Literature

Over the last few decades, a number of studies attempted to explain depletion of natural resources, fuel usage (or equivalently, energy consumption), and the relationship between resource depletion and development, as well as examined the relationship between energy consumption and development.

For instance, Tilton (1989) explains the decline of mining and mineral processing in North America from the perspective of demand. Kim et al (1989), based on the disaggregated categories of demand, develops the dynamic model of groundwater depletion. Martinet and Doyen (2007) examine the conditions for the sustainability of a production–consumption system based on the use of an exhaustible natural resource. The study addresses the discussions on the sustainable level of consumption, the natural capital to preserve, and the substitutability between ‘‘man-made’’ and natural capital, and highlights the role of the technology in the sustainability of the economy. Vuuren et al (2010), based on a simple production and trade model, explore the sustainability of current phosphorus flows in terms of resource depletion and the ultimate fate of these flows. According to their estimates, depletion of phosphate rock is around 20–35%. In worst case scenarios of low resource base, about 40–60% of the current resource base would be extracted by 2100.

Efforts to examine natural resource depletion and development have been seen in the literature. Pegg (2004) evaluates relationship between mining and poverty reduction. He claims the reality of mineral-led development has not lived up to its rhetorical promise that mining can contribute to poverty alleviation, unless a variety of demanding preconditions are met. Kilian et al (2009), based on the investigation of the relationship between oil shocks and external balances, argue that the effect of oil demand on the trade balance depends critically on the response of the non-oil trade balance. Schilling and Chiang (2011) examine the effect of natural resources on a sustainable development. They argue 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. Prior et al (2011) explore the economic and productivity impacts of peak minerals, and how changes in the mineral production profile are influenced by technological and scarcity factors as well as environmental and social constraints. They argue that incremental innovation to address the social or environmental consequences of mining could delay the peak in resource production, but that radical innovation (e.g. production from recycled or recovered resources) can foster a lengthier, more sustainable reliance on the resource.

Similarly, a huge literature exists on the impacts of fuel (or energy) on development, demonstrating solid theoretical and practical background for one to investigate the correlation between the above two issues. For instance, Dunkerley and Ramsay (1982) argue that higher prices of imported fuels contributed to accelerate inflation and to lower economic growth. They also link the ways in which the oil-importing developing nations finance rising oil imports to global peach, 'if the oil-importing developing countries are unable to afford more oil, their growth rate will suffer, threatening major export markets for the industrial countries and regional and global peace.' Halicioglu (2009), using the time-series data for the period 1960–2005, empirically examines the dynamic causal relationships between carbon emissions, energy consumption, income, and foreign trade in Turkey. He identifies two forms of long-run relationships between the variables: carbon emissions are determined by energy consumption, income and foreign trade; and income is determined by carbon emissions, energy consumption and foreign trade. You (2011) examines the long-term

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dynamic relation between China's energy consumption and sustainable economic growth. The analysis finds that renewable energy consumption promotes sustainable development for both natural and economic societies, while increase in traditional solid energy consumption is more likely to benefit only the growth of GDP. De Freitas and Kaneko (2011) assess the changes in CO2 emissions from energy consumption in Brazil. Their analysis shows that emissions change has been predominantly influenced by economic activity and population growth. Similar analysis, which is based on cointegration tests, can be seen from a variety of studies such as Say and Yucel (2006), Alam et al (2007, 2011), Ang (2007, 2008), Lise and Montfort (2007), Erdal et al (2008), Huang et al (2008), Apergis and Payne (2009), Odhiambo (2009), Ugur and Sari (2009), Ziramba (2009), Chang (2010), Ghosh (2010), Ozturk et al (2010), Niu et al (2011), Belke et al (2011), Pao et al (2011), Sadorsky (2011), Zhang and Ren (2011).

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 Modelling Mineral Depletion

The depletion of mineral in Fiji is likely to be affected by domestic demand, external demand and demand for financing fuel import bills. An increase in domestic demand will increased the depletion of the 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. Hence, domestic demand, external demand and energy consumption are expected to have positive coefficients in the model of explaining mineral depletion in Fiji.

In addition, these demands are further likely to be influenced by some other factors, including those specified in the system. For example, domestic demand can be explained by factor inputs including energy, capital and labor. 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.

Besides the demand perspective, mineral output could also be explained from the production perspective. Though there is inadequate database in Fiji on factor inputs in the mining sector, the high correlation (with correlation coefficient of 0.98) between nominal mining output and nominal GDP provides strong support for one to use the trends of factor inputs at the national level to reflect the trends of factor inputs in the mining and quarrying sector. Therefore, the model designed in the current study implicitly incorporates capital, labor and energy inputs to investigate mineral output through domestic demand and external demand. More specifically, the two variables not only represent demands but also factor inputs.

The mechanism discussed in the above is structurally demonstrated in Figure 1, and can be summarized in the following simultaneous equations system:

(1) $\ln(\text{mineral})_t = \beta_0 + \beta_1 \ln(\text{GDP\_m\_ex})_t + \beta_2 \ln(\text{exports})_t + \beta_3 \ln(\text{energy})_t + \beta_4 \text{instability}_t + e_t$

Where

$\ln(\text{GDP\_m\_ex})_t = \alpha_0 + \alpha_1 \ln(K)_t + \alpha_2 \ln(L)_t + \beta_3 \ln(\text{energy})_t + u_t$

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

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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);

exports captures the external demand (at 2005 prices, US dollars);[1]

energy is energy consumption (million kilowatts hours);

K and *L* are capital stock and labor force;[2]

exchange rate is Fiji dollars per US dollar;

rural is rural population. It is taken as the inverse measure of urbanization; 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 Modelling Development Sustainability

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 one of explanatory variables in order to find out whether mineral depletion in Fiji is for the purpose of domestic economic development. However, the linkage between mineral depletion and the domestic demand could also run from the other way around. 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 the 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) $\ln(\text{incpc})_t = \theta_0 + \theta_1 \ln(\text{mineral})_t + \theta_2 \ln(\text{kpc})_t + \theta_3 \text{instability}_t + \theta_4 \ln(\text{incpc})_{t-1} + \varepsilon_t$

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

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

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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;

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. The mining is expected to have a positive sign as mining activity contributes to economic activity and income. Equation (3) assesses CO_2 emissions to identify main contributors to the deterioration of the environment. We presume that mining activity is likely to contribute CO_2 emissions and hence will have negative impact on environment. And 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 the life expectancy while CO_2 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, includes mining and quarrying output, energy consumption, GDP, exports, world fossil fuel price, consumer price index, and exchange rate. Dataset for this part covers the period 1970-2006. The second part of the current study, which tries to assess mineral depletion's impact on development, requires more series such as CO_2 emission, GDP, total labor force, gross fixed capital formation, life expectancy, energy consumption, education index and population in the rural area. Dataset for this part covers the period 1980-2006. Moreover, based on the information on natural disasters, coups and policy changes, a dummy variable named *instability* is created by authors to capture social instability in Fiji.

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Data sources include Fiji Bureau of Statistics, World Bank, IMF and the UN Human Development Index. Table A1 in Appendix summarizes sample statistics of some variables mentioned in the above. Figure A1 presents time trend of the variables under consideration, and Figure A2 presents scatter plots between pair-wise variables.

4. Empirical Results

4.1 Unit root test

Before proceeding to estimate the various models, all variables were tested for stationarity. Based on augmented Dickey-Fuller unit root test and Phillips-Perron unit root test, all variable were found to be integrated of order one.[3] The unit root tests validate the forms that the variables enter the model, as specified in Equation (1).

4.2 Regression output: Part (I)

Before finalizing the determinants of mineral depletion, we proceed to examine whether there exists long-run relationship(s) between variables under investigation. Based on Engle-Granger and Johansen cointegration tests (test results are not reported due to space limitation), 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. And the causality problem will be taken care of by means of two-stage least squares (TSLS) and generalized method of moments (GMM) estimation procedures, which will be discussed in below.

To investigate the hypotheses discussed in the above context, the OLS estimator is initially employed. The performance of all three explanatory variables seems to be within expectation. See column (1) in Table 1. The diagnostic statistics in Table 1 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).

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). In the original model, $\ln(\text{mineral})_t = \alpha_0 + v_t$,[4] 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.[5]

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), particular 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 1). 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). And $\ln(\text{mineral})_{t-1}$ 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. TSLS and GMM estimators were therefore adopted to correct for the endogeneity problem. Instrumental variables (IVs) for the problematic $\ln(\text{GDP\_m\_ex})_t$ include ln(energy) and $\ln(\text{GDP})_{t-1}$,[6] and $\ln(\text{mineral})_{t-1}$, $\ln(\text{exchange rate})_t$ and $\ln(\text{rural population})_t$ for the problematic $\ln(\text{exports})_t$.[7] We also tried to control for the weak exogeneity of $\ln(\text{mineral})_{t-1}$ by using $\ln(\text{mineral})_{t-2}$ as the IV.[8] However, neither the TSLS nor GMM estimator supports this practice since estimates turned out biased and inefficient. We therefore proceed our analysis without controlling for the weak exogeneity of $\ln(\text{mineral})_{t-1}$. The first-stage OLS regression results, which are only indicative in explaining $\ln(\text{GDP\_m\_ex})_t$ and $\ln(\text{exports})_t$, are reported in the lower panel of Table 1.

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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 1.

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 0.08 percent. Fiji, when compared to Mauritius, had similar rates of growth in the 1970s and early 1980s (Prasad and 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

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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 purpose. This finding is consistent with the fact that domestic construction activity creates a demand for domestic minerals, which in this case refer 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 the answers to questions such as ‘whether mineral depletion benefits the Fijian economy’, and if yes, ‘whether the economic gain is at cost of environmental degradation and human capital’. Positive answers to the above questions should be evidence for development sustainability 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 summarized in

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Table 2.

Interpretation of regression results presented in this section requires special caution because the estimates may be biased because of an insufficiently large enough sample for each regression in Table 2. 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 2 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 surprise one that the model suffers from the autocorrelation problem due to the problem of omitted 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 2 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 development sustainability question. In column (2) the estimated partial slope parameter of the income per capita variable indicates that, given other factors

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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. And the fact is terrifying because gaining 1 tonne of carbon dioxide per person within the past two decades has been seen in Fiji (see Figure A1).

Concluding remarks and policy implications

To summarize, the current empirical analysis finds strong evidence that mineral depletion in Fiji is driven by domestic economic development demand, external demand and the demand of paying 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 imposes burdens on maintaining environmental sustainability and development sustainability, since it increases carbon emissions and reduces life expectancy in Fiji. Though empirical findings in the second part of the analysis may not be robust, it is indicative enough to alert us to think seriously about the long-run development sustainability issue in terms of social and environmental benefits.

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 '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 the 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 (Commonwealth of Australia, 2006). 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. There are examples of small countries in the Pacific where the story has not been a happy one. For example, Nauru had large deposits of phosphate and during its peak period, and Nauruans had a per capita income which was the third highest in the world. However, mismanagement and lack of good investment of the revenues for the future generation, Nauru today has become a poor country with little phosphate.

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

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

[3] Test results are not presented in this paper due to space limitation, but available upon request.

[4] For the simplicity of demonstration the other explanatory variables are dropped.

[5] 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 $\ln(\text{mineral})_t = \alpha_0 + \alpha_1 \ln(\text{mineral})_{t-1} + \rho v_{t-1} + u_t$.

[6] $\ln(\text{GDP})_{t-1}$ 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 labor force and capital stock, due to a reasonably high

correlation, with correlation coefficient of 0.844, between $\ln(GDP\_m\_ex)_t$ and $\ln(GDP)_{t-1}$.

[7] The variable $\ln(mineral)_{t-1}$ 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 $\ln(exports)_t$. And the Durbin-Wu-Hausman test further confirms the exogeneity of $\ln(mineral)_{t-1}$ in the model of $\ln(exports)_t$ with test statistic $chi^2 = 1.037$ and p-value = 0.308.

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

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Table 1. Regressions on ln(mineral)$_t$

ESTIMATION METHOD	(1) OLS	(2) 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(mineral)$_{t-1}$		0.408[4.92] ***	0.402[3.64] ***	0.424[4.38] ***
ln(exports)$_t$	0.812[9.15] ***	0.568[6.61] ***	0.595[4.11] ***	0.551[3.93] ***
ln(GDP-mineral-exports)$_t$	0.221[5.23] ***	0.138[3.77] **	0.130[2.07] **	0.102[1.68] *
ln(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
Drubin'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(mineral)$_{t-1}$	2.70 (0.100)
ln(exports)$_t$	3.62 (0.057)
ln(GDP-mineral-exports)$_t$	22.56 (0.00)
ln(energy consumption)$_t$	0.53 (0.465)

First-stage of TSLS		
	ln(exports)$_t$	**ln(GDP-mineral-exports)$_t$**
Constant	24.991[7.17] ***	-9.145 [-1.77] *
ln(mineral)$_{t-1}$	0.226 [2.01]***	
ln(exchange rate)$_t$	-0.447[-3.12]***	
ln(rural population)$_t$	-2.073[-4.64] ***	
ln(GDP)$_{t-1}$		1.303 [5.30] ***
ln(energy consumption)$_t$		0.221 [3.92] ***
Sample size	37	36
Adjusted R-squared	0.5192	0.7018

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

(to be continued ...)

(Continued)

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 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.

Table 2. Modelling Development Sustainability 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 to that in Table 1.
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 labor 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 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.

Appendix

Table A1. 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 A1. Trends of Time Series in Fiji over 1970-2010

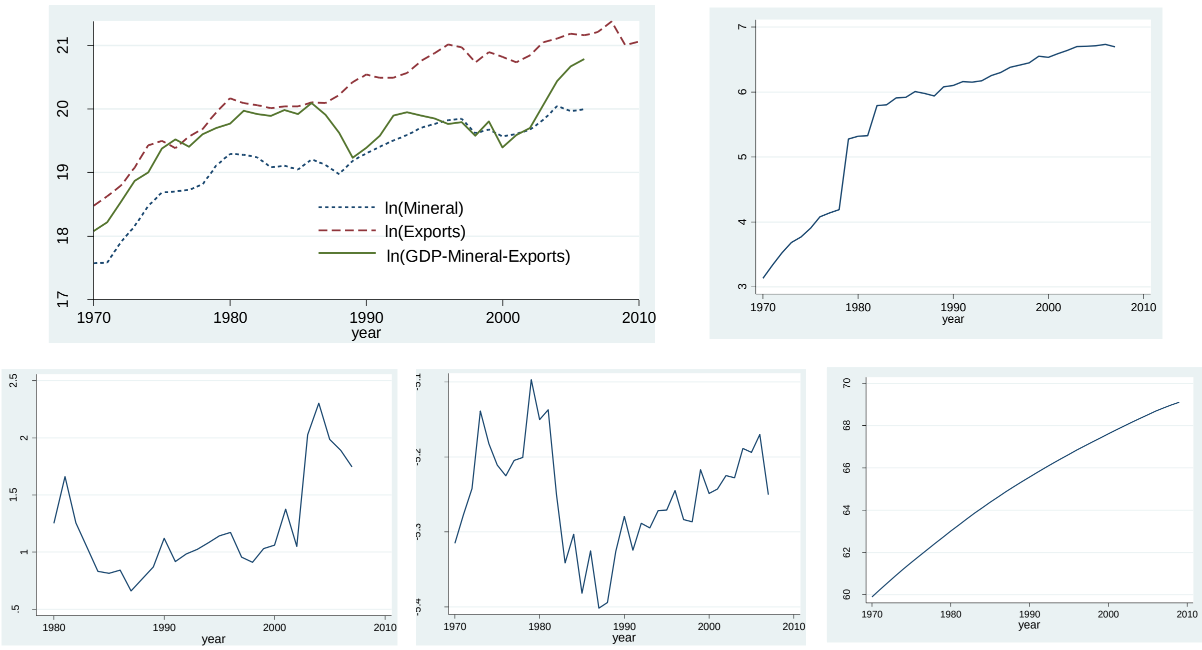

Figure A2. Scatter Plots between Time Series in Fiji over 1970-2006