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Intensity of Use Hypothesis: Analysis of Selected Asian Countries with Structural Differences

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ABSTRACT: Several efforts have been made to estimate the relationship between intensity of metal use and per capita income at different levels with results supporting the hypothesis that metal consumption per unit of GDP initially increases, peak and later decline with rising income per head. This paper estimates the intensity of copper use curves for three Asian countries with different economic structure to show that the I-U hypothesis significantly underplay the influence of economic structure and other technological innovations by its exclusive emphasis on per capital income. The results are in general conformity with the notion that the intensity of material use (I-U) is higher for industrial and very low for service based economies. Though the finding is mixed in the agrarian country considered, the paper suggests the need for further research to corroborate this outcome.

Keywords: Asian countries; economic development; technological change; mineral resources; material use; metals.
JEL Classifications: O1; O3; Q3

1. Introduction

Intensity of Use (I-U) is perhaps the most widely used measure of the quantity of materials used to produce goods and services, and is often intended to be a précis estimate that connects the use of a material(s) to trends in the output of an economy at both the aggregated and disaggregated levels. I-U ordinarily is defined as the ratio of materials use to value added, which in the case of an economy is equivalent to gross domestic product (GDP) (Considine, 1990; 1991). The intensity of use of any mineral product therefore depends on the amount of that mineral consumed both directly and indirectly per unit of output of each final good or service produced in the economy and the output of each final good and service. According to this hypothesis, the intensity of use of a product is the mix of goods and services produced in any economy and the mix of materials used to produce those goods and services and is a function of economic development measured by real per capita income.

In very poor countries, whose economies largely consist of non mechanised subsistence agriculture, the intensity of material use is low. As development takes place, manufacturing, construction, and other material-intensive sectors grow while the share of agriculture in GDP declines. This causes intensity of use to rise. At some point, however, the growth in demand for new houses, roads and refrigerators starts to slow, and consumer preferences shift toward services, computers, and other less metal-intensive goods. As a result, intensity of use eventually rises, and then falls as development proceeds.

There is a general tendency for countries to export traditional manufactured products, which are material intensive, and import services and higher technology products at their early stage of industrialization. When economic development occurs and income per head rises, a shift in the converse direction often occurs. For these reasons, the intensity of use hypothesis anticipates an inverted U-shaped relationship, with intensity of use first rising and then falling with growing per capita income.

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However, the extraordinary focus of the intensity of use hypothesis on per capita income is disturbing. There are two elemental reasons why intensity of use may change with time; either as a result of changes in the mix of materials used to produce individual goods or from the product composition of income. While income per capita may be a realistic proxy for the net outcome of the different factors shaping trends in the mix of goods produced by the economy, it obviously does not capture the major trends in the material composition of products.

One outcome of the tendency for intensity of use to vary with the level of economic expansion is that a similar inverted U-shaped curve should be apparent from cross-sectional comparisons between countries. This, according to Crowson (2008) is hardly the case as the patterns may be different for any two products. This signifies that each product needs separate analysis on the one hand and reflects the differences in the natural resource endowments of individual countries on the other. In addition, it highlights some of the weaknesses of the intensity of use hypothesis.

Accordingly, the study set out to estimate the intensity of copper use in selected newly industrialised countries of South East Asia using regression techniques. Alternative specification will be considered along with the inclusion of some variables that are likely to influence intensity. The essence of this particular effort is to see if, and to what extent do factors aside incomes affect the intensity of use.

The attempt made in this paper is important for a number of reasons. First, with the exception of the study on the intensity of copper use for Japan by Guzman et al, (2005), major efforts at investigating the determinants and or the effects on intensity of these determinants are quite few. At least the 'state of the debate' cannot be the 'end of debate'. Second, changes in the structure of final demand occasioned by the nature of a country's productive activities have been argued to exert significant impact on resource use. The general assumption is that predominantly agricultural or service based economies will use lesser quantity of a given materials (say metals) to produce a given worth of output compare to a manufacturing based (see Jänicke et al., 1997; Crowson, 1998; 2008). By estimating the intensity of use for countries with these structural differences, the present paper makes little contribution to knowledge. Finally, the outcome of a study of this nature can have significant implication for understanding intensity of resource use in constantly changing structure of most emerging economies from agriculture to industrial particularly in the South East Asia (e.g. Malaysia, Thailand and Philippines).

The rest of the paper is organised into three sections. Following this introduction is a discussion on the framework and general composition of intensity of material use. The third section covers the empirical analysis while the last section offers some concluding remarks and suggestions.

2. Intensity of Use: Framework and Composition

Intensity of Use is determined by two components. The first is the material content of the products, which reveals changes in the mix of materials used to produce the goods and services. The second is the product composition of income, which signifies changes in the mix of goods and services produced in an economy. Several factors that can influence the two variables above and hence the I-U are well documented in the literature. Cleveland and Ruth (1999) identified five of these factors from previous literature. These are Technical improvements; Substitution possibilities in end use; pattern of final demand; saturated markets for basic materials; and government's regulations[2]. They however noted that there are other variables that determine the I-U of a material, and those described are not independent of each other.

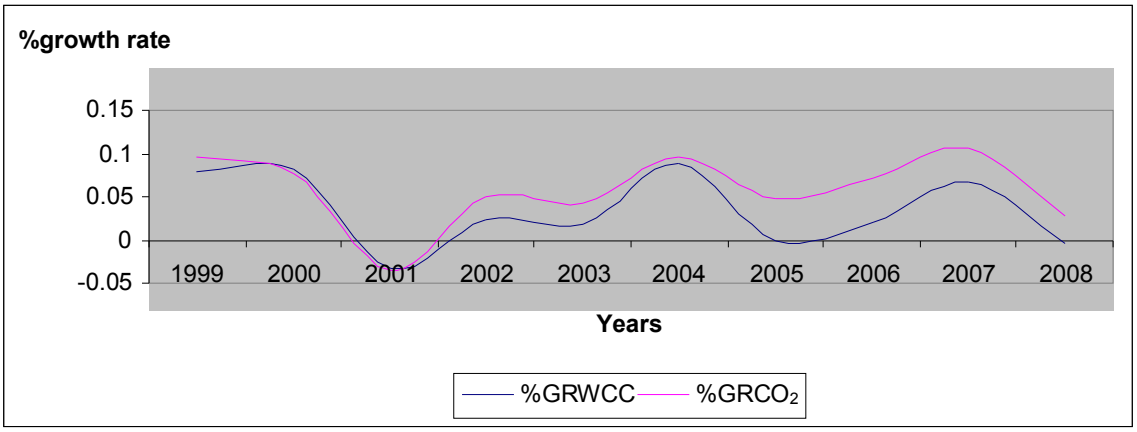
Contrary to conventional wisdom that innovations resulting from changing technology usually result in falling usage of materials, Crowson (2008) observe that the use of copper and metals greatly increased in the late nineteenth century by the development of telephone networks and catalytic converter for car exhaust systems respectively. Resulting from the above is the tendency for certain regulation to indirectly prompt a sizable rise in the demand for or use of materials such as the platinum group metals (the catalytic converter for car exhaust) due to imposition of emission controls on automobiles.

[2] Explanation on how these factors determine the I-U is basic across studies and it is discuss in the Cleveland and Ruth article. So the paper sees the replication as unnecessary and is avoided here.

Figure1 below shows the annual growth rate of world consumption of refined copper and CO^2 emission between 1998 and 2007. The trend suggests that a degree association exist between the two variables in the last decade. The correlation coefficient of about (-0.25) may be taken to suggest that additional reductions in emissions resulting from emission regulations and the attendant innovations has been met with lower material (copper) consumption. This claim however might require additional evidence.

Aside the above determinants of the I-U, few other factors grossly overlooked in the literature but pointed out in Crowson (2008) are considered below

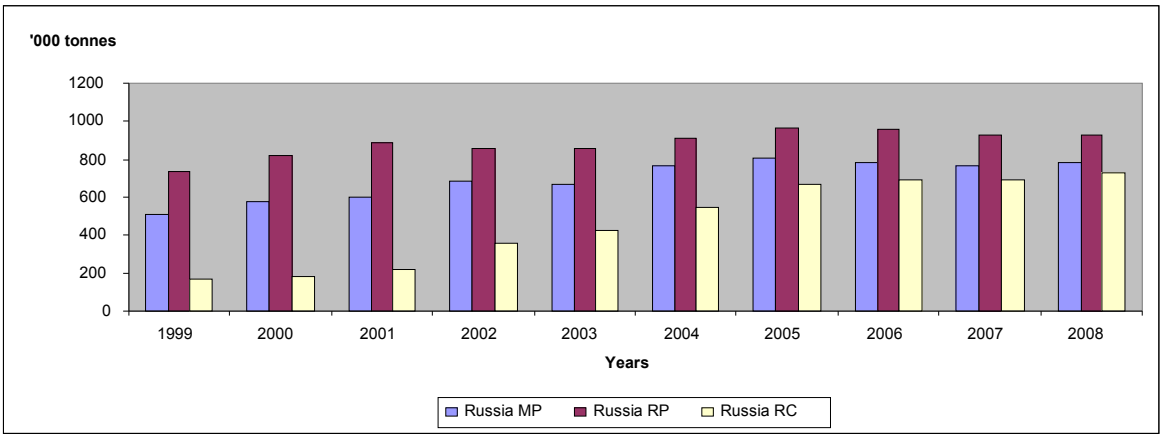
Figure 1. World Copper Consumption and CO_2 Emission



***Sources*:** Computed using data from WBMS monthly bulletin and World Bank WDI

- **Impact of Resource Endowments:** variation in the **i**ntensity of use may be a reflection of mineral endowments rather than per capita GDP. The line of reason here is that countries are likely to use more of materials that can be sourced or produce locally to ensure security of supplies as against excessive reliance on imports except where there is no local production[3]. The mine production (MP) as well as the consumption (RC) and production (RP) pattern of refined copper for the US, China and Russia between 1999 and 2008 are shown below in figure 2 to 4. The three countries ranked among the top ten according to copper mine production. A close look at figure 2 shows that Russia's consumption of refined copper rose steadily in the study period but remained within the limit of mine and refined production.

Figure 2. Russia's Mine Production, Refined Copper Consumption and Production

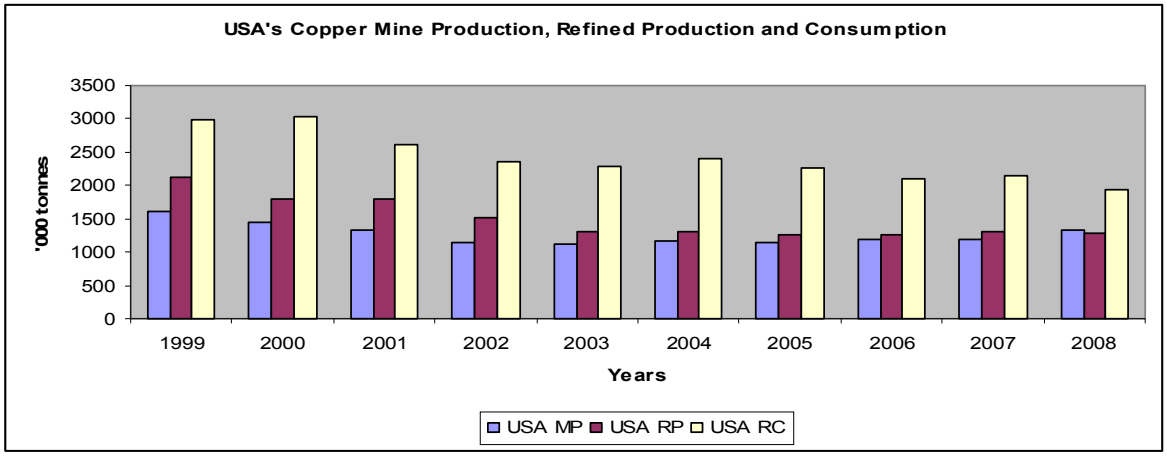


***Source*:** Computed with data from World Bureau of Metal Statistics (WBMS) monthly bulletin

[3] Exceptions to this are countries that are typical non producing countries. In this case, demand will be sourced externally.

In the case of the USA, figure 3 reveals that consumption of refined copper is generally higher than the country's production capacity for both mines and refined production. There is a general downward trend in refined copper consumption from year 2000. What this suggests is that the ratio of production to consumption is rising.

Figure 3. USA's Mine Production, Refined Copper Consumption and Production

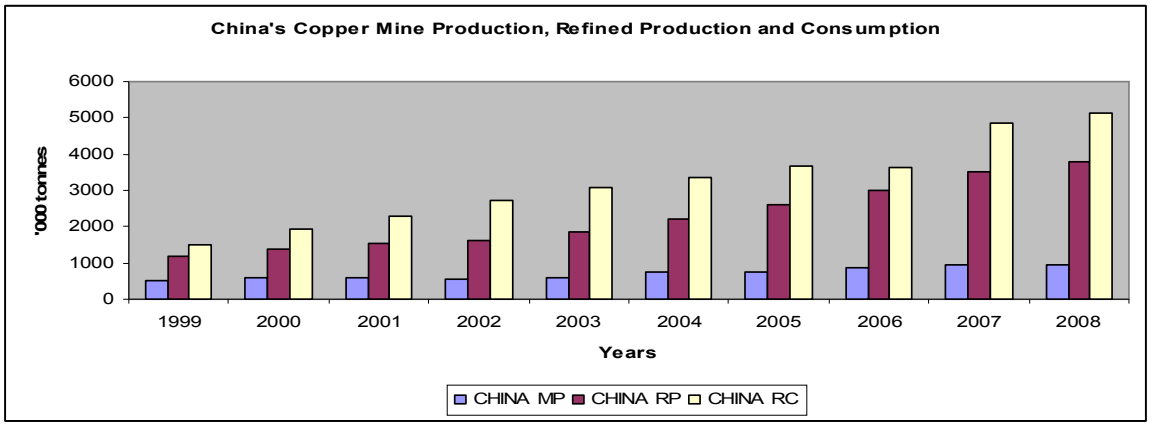


***Sources*:** Computed with data from World Bureau of Metal Statistics (WBMS) monthly bulletin

The China's case presented in figure 4 shows that both refined copper consumption and production has been rising indicating that a greater proportion of consumption is refined locally.

This Picture painted in the three trends above is not surprising given the value attached to material supply security in developed countries. The degree of refined copper consumption sourced domestically is presented below for USA and China. A significant proportion of consumption is been determined by production over the years in both countries. However one clear feature from this picture is that material use has moved at different rates and in disparate directions in various countries and these differences in themselves do not necessarily mean corresponding divergences in the rates of growth of demand

Figure 4. China's Mine Production, Refined Copper Consumption and Production

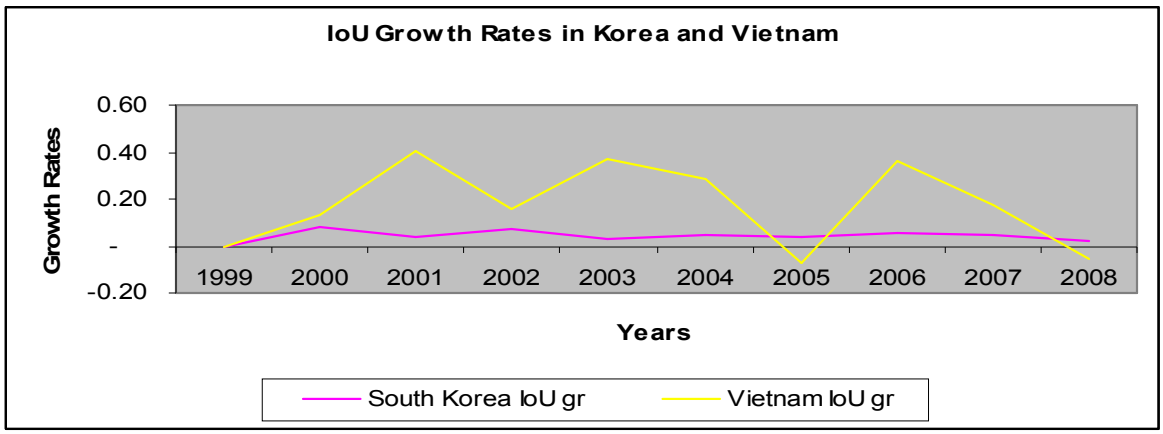


***Sources*:** Computed with data from World Bureau of Metal Statistics (WBMS) monthly bulletin

- **Present level of Development:** Given that different regions and countries are at different phases of economic development, it is expected that their intensity of material use for minerals e.g. copper will display strikingly different pattern. The more established economies particularly from Europe basically have complicated and entrenched infrastructure and their citizens have high levels of ownership of housing, consumer durables as well as automobiles. Much annual demand is merely for replacement rather than to add to the existing stock. In sharp contrast, most developing economies devote a significant share of their annual spending on investment and capital spending. Figure 5 below clearly indicate this when the annual growth rate in the intensity

of copper use of a more matured economy like Singapore (a member of OECD) is compared to Vietnam, a typical developing economy and Non OECD. Both countries are from Asia

Figure 5. Growth in I-U for South Korea and Vietnam 1999 - 2008

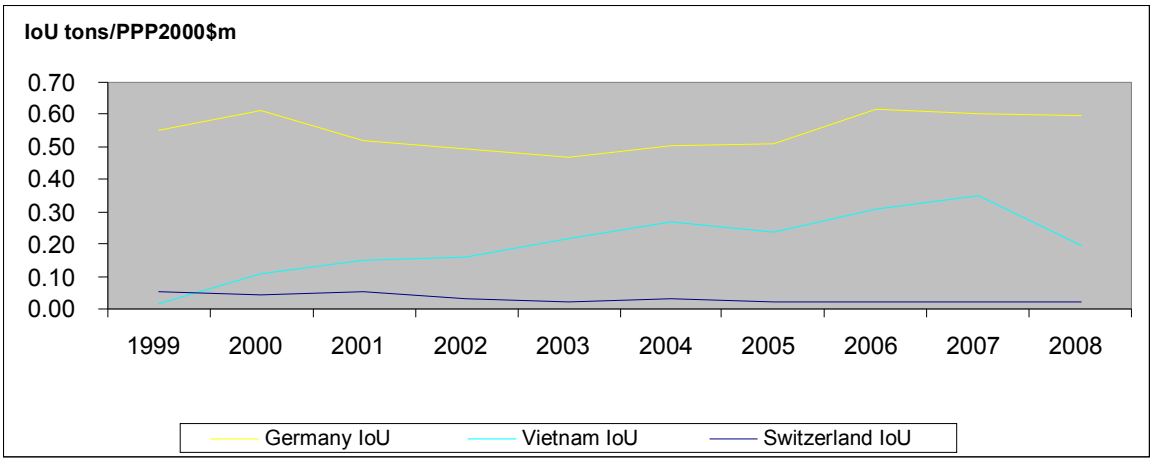


***Sources*:** Computed using data from WBMS monthly bulletin and IEA

- **Economic Structure/Nature of Productive Activities:** The natural history of a country's economic formation, which is partly dictated by its demography and natural features, is a key factor that determines level of material usage. Some types of economic activity are more minerals intensive than others. A predominantly agricultural economy, like Vietnam, will have different needs and patterns of consumption of mineral products from a typical manufacturing nation, such as Germany, whose requirements will in turn differ from one that is largely based on services, like Switzerland. Likewise an economy with a sustained high ratio of capital to current expenditures will use more mineral products than in converse situation. Construction of all types, business investment and a host of other capital expenditure spending are much more materials intensive than consumption spending.

The broad message here is that it is possible for economies with comparable per capita incomes to have broadly different intensities of use of particular materials resulting from the nature of their productive activities. A country that specialises in manufacturing export will have very different intensities than an agrarian economy that imports manufactured goods while a country largely based on services will have much lower intensities than others.

Figure 6. Intensity of Use for Germany, Vietnam and Switzerland 1999-2008



***Sources*:** Computed using data from WBMS monthly bulletin and IEA

In Figure 6 above, the intensity of use (I-U) is computed for three countries with different economic structures. The dominant productive activities in Germany, Vietnam and Switzerland are

Manufacturing, Agriculture and Services respectively. The trend of the I-U follow the pattern discussed above with the I-U of a typical industrial based economy being the highest followed by Vietnam, a predominantly agricultural based economy while a service based economy has a very low intensity of use.

3. Empirical Analysis

3.1 *Estimating the I-U Curves*

In this section, the paper tests the intensity of use hypothesis by estimating some equations which link the I-U of copper as a function of economic development. The I-U is tons of refined copper consumed annually per million dollars of real gross domestic product (GDP) while economic development is measured by real per capita income. This study uses the basic traditional model[4] and an extended version by Guzman, et al (2005) to estimate the intensity of use for three countries using time series covering the period of 1980 to 2010.

The basic model assumes that the intensity of copper use for a country (I-U) is a function of the country's product composition of output which in turn depends on the economy's real income per head (IPH). This is functionally expressed as:

$$I\text{-}U_t = C_t/GDP_t = f\ (IPHt) \quad (1)$$

In other to accommodate the inverted U-shape relationship, hypothesised between the two variables, a quadratic relationship is assumed. Hence, equation 1 becomes

$$I\text{-}U_t = \mu_o + \mu_1 IPH + \mu_2 IPH^2 + e_t \quad (2)$$

μs are parameters to be estimated and e_t is the error term assumed to be distributed normally.

Since the assumption underlying the hypothesis is for intensity to rise first and then decline with rise in income per head, μ_1 is expected to be positive and μ_2 negative.

Guzman et. Al., (2005), noted that the above specification ignore the likelihood of correlation between income per head and time which often arise and whose effects may bias the estimated parameters and proceeded to estimate a time linear and exponential time version of the model[5]. The time linear address this shortcoming by including a time trend as an independent variable in equation 2 above as shown in equation 3 below

$$I\text{-}U_t = \mu_o + \mu_1 IPH + \mu_2 IPH^2 + \mu_3\, t + et \quad (3)$$

All variables are as defined with the same a priori expectorations and the time parameter is expected to be negative. The relevance of the above speculation lies in its implicit assumption that the net impact of all variables aside income per head, affecting the intensity of use is very much correlated with time. For a major metal like copper, this assumption cannot be overlooked.

3.2 *Results and Interpretation*

The intensity of use of refined copper in South Korea, Singapore and Vietnam (three countries from the Asian region) were estimated with equations 2 and 3 for the period of 1980 to 2010. The least square regression techniques were used for the two equations. The annual time series for the countries' income per head measured in term of real 2000 US dollars obtained from the World Bank WDI (2011). I-U for these countries is measured as tons of copper consumption divided by the GDP in 2000 US dollars obtained from WBMS monthly bulletin (2011). An incremental value of (0, 1… n) is assumed for the time variable.

Both the traditional and the linear time model produced mixed results but the estimates from the latter were better, hence the paper reports the results of the linear time model here. Generally, equation 3 is an improvement over equation 2 on the grounds that it does not consider the impact of technological innovation and other determinants of intensity that may take place in the course of time. This will in turn bias the statistical estimates.

The results are contained in Table 1. In the case of South Korea, the coefficient of the income per head (IPH) is positive and those of the (IPH^2) and the time are negative. All but the time variable is significant at 95 percent confidence limits. What this outcome suggests is that the intensity of copper use in South Korea initially rose and subsequently falls with income per head in the period of study. The statistical significance of the time variable suggests that the impact of technology and similar

[4] The traditional model is identical to that used by the international Iron and Steel Institute (1972).

[5] This study ignores the exponential time model under the assumption that though time related variables may reduce intensity but certainly not by a fixed percentage.

variable on the intensity of material use in South Korea is notable. The intensity of use curves in figure 7 also attest to the relevance of this hypothesis for a manufacturing based economy like Korea.

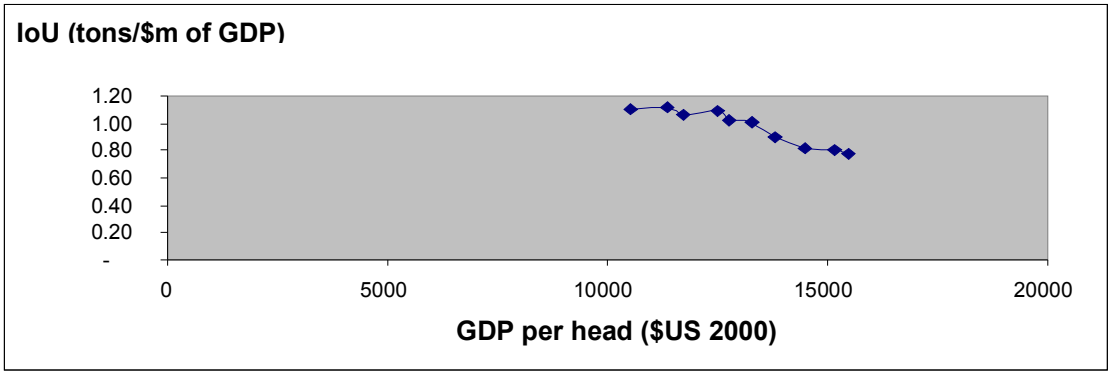
Table 1. Estimated Results for the I-U in Korea, Singapore and Vietnam

Linear Time Model	$I\text{-}U_t = \mu_o + \mu_1 IPH + \mu_2 IPH^2 + \mu_3 t + e_t$		
Estimates	South Korea	Singapore	Vietnam
μ_1	0.000193 (4.382422)***	-3.91E-11 (-0.795389)	0.000384 (1.856746)*
μ_2	-8.14E-09 (-1.919309)*	1.20E-09 (6.198056)***	-3.81E-07 (-0.621449)
μ_3	-0.030538 (-0.835835)	-0.020336 (-16.25443)***	-0.028569 (2.164936)**
Adjusted R2	0.9237	0.8320	0.8924
DW	1.979	2.376	2.409
Schwarz Criterion	-3.4498	-6.8784	-4.2463

Results from least squares regression.

T-values are in ( ); *, **, *** shows 10%, 5%, and 1% level of significance respectively.

Figure 7. Intensity of Use Curves for South Korea 1980-2010



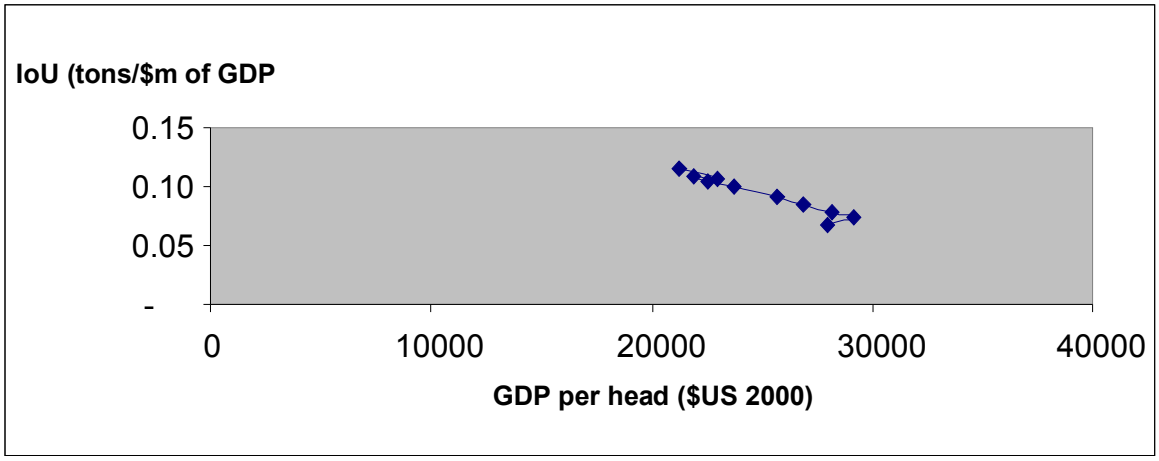
Sources: Computed using data from WBMS monthly bulletin and WDI

The result for Singapore even after controlling for time effect did not show considerable support for the intensity of use hypothesis. The negative sign for IPH suggests that I-U does not rise with income per head while the sign and statistical significance of IPH^2 confirm that the inverted U-shape does not apply also. This outcome gives credence to the notion that not only is Service based economies I-U very low but their material use is independent of the level of development (defined by per capita income).

The time variable appear with the right sign and it is statistically significant attesting to the fact that intensity of use in such predominantly service based economies are explained better by factors associated with time. The intensity of use curve in figure 8 below shows that the I-U fell in the year 2000 and remains relatively flat till year 2004 despite the fluctuations in GDP per head during the period. Above all, it is clear that the intensity of use is remarkably low compared to that of a manufacturing economy.

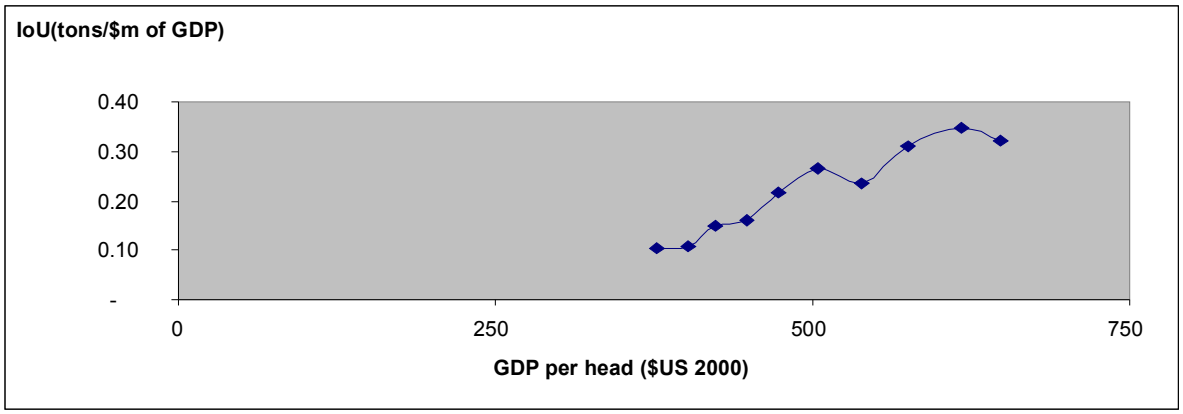
The estimated results for Vietnam are similar to that of Singapore with all the variables exhibiting the right signs and significance at conventional levels. From the GDP per head statistics, there is a picture of a relatively low income and underdeveloped economy. In figure 9 below, though the I-U are higher than that of Singapore, they are substantially lower to that of South Korea. This also corroborates the notion that Agrarian economies have lower intensity of metal use than industrial economies.

Figure 8. Intensity of Use Curves for Singapore 1980-2010



***Sources*:** Computed using data from WBMS monthly bulletin and WDI

Figure 9. Intensity of Use Curves for Vietnam 1980-2010



***Sources*:** Computed using data from WBMS monthly bulletin and WDI

4. Conclusions and Recommendation

Many attempts have been made to estimate the relationship between intensity of metal use and per capita income at country, regional and global levels with results supporting the intensity of use hypothesis. The import of this present effort is to see if the hypothesis (i.e. the tendency for metal consumption per unit of GDP to initially increase, reach a peak and then decline with rising income per head) holds for all countries or is influenced by the predominant economic activities of countries. After controlling relevant technological changes over time, the following conclusions can be drawn from the estimated results for the intensity of copper use in selected Asian region.

- The intensity of use hypothesis' over reliance on income per head is too restrictive as it ignores vital country specific features like economic structure or major economic activities
- Intensity of use for metals particularly copper is higher in predominantly manufacturing economies than service and even agrarian economies whose intensity may be higher for agriculture related inputs
- Predominantly service based economies have very low intensity of use for metals.

This study is based on copper and analyse intensity of material use of countries from the same region for a period of 1980 to 2010. As important and recent as this metal type and sample period are respectively, different metals and larger sample size can yield more insightful results. Additional efforts may be required before these conclusions are generalised. To this end, we suggest that further studies should explore these possibilities by considering more metals for longer periods in several countries from different regions.

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