GLOBAL PANEL DATA MODELLING OF INDUSTRIAL OUTPUT

AZFAR HILMI BAHARUDIN

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ABSTRACT

This study estimates panel data models of industrial output by means of fixed effects, time fixed effects, random effects and pooled panel data models. The models are specified for the main data set which includes all available countries and subsets of countries according to income levels i.e. low income countries, lower middle income countries, upper middle income countries and high income countries. Hausman tests reveal that fixed effects model is appropriate for all countries model, low income countries and upper middle income countries. Meanwhile, fixed time effects model is appropriate for high income countries and Chow stability test reveals that pooled panel data model is appropriate for lower middle income countries. Diagnostic analyses of estimated models indicate that all models suffer from the problems of cross sectional dependence, non-constant variances and serially correlated errors. As such, this study applies robust standard error estimators and derives its final conclusions based on the most reliable results. Based on robust fixed effects model, household consumption, government consumption and money supply are statistically significant regressors for the global economy's industrial output. Meanwhile, government consumption, money supply, interest rate and trade openness are statistically significant regressors for industrial output in low income countries. Based on robust pooled panel data model, all regressors are statistically significant for lower middle income countries. Robust fixed effects model of industrial output for upper middle income countries reveal that household consumption, government consumption, money supply and inflation are statistically significant. While the regressors that are statistically significant for industrial output in high income countries based on robust time fixed effects model are household consumption, government consumption, factor years of 2009 and 2010.

ABSTRAK

Kajian ini mengukur pengeluaran industri dengan kaedah model statistik kesan tetap, kesan tetap masa, kesan rambang dan gabungan. Model dispesifikasikan untuk pengeluaran industri global secara keseluruhan dan mengikut klasifikasi negara berdasarkan pendapatan iaitu negara berpendapatan rendah, rendah sederhana, tinggi sederhana dan tinggi. Model kesan tetap sesuai untuk negara data set keseluruhan, data negara berpendapatan rendah dan tinggi sederhana. Manakala model kesan tetap masa sesuai untuk negara berpendapatan tinggi dan model gabungan sesuai untuk negara berpendapatan rendah sederhana. Ujian diagnostik menunjukkan bahawa semua model mengalami masalah terma sampingan. Untuk mengatasi masalah tersebut, kaedah pengukuran model yang lebih tepat telah digunakan. Berdasarkan kaedah tersebut, perbelanjaan isi rumah, perbelanjaan kerajaan dan penawaran wang adalah faktor penting dalam menentukan pengeluaran industri global. Manakala, perbelanjaan kerajaan, penawaran wang, kadar bunga dan keterbukaan perdagangan adalah faktor penting untuk negara berpendapatan rendah. Semua faktor adalah penting untuk pengeluaran industri berpendapatan rendah sederhana. perbelanjaan isi rumah, perbelanjaan kerajaan, penawaran wang dan inflasi adalah faktor penting untuk pengeluaran industri negara berpendapatan tinggi sederhana. Manakala faktor penting untuk pengeluaran industri untuk negara berpendapatan tinggi adalah perbelanjaan isi rumah, perbelanjaan kerajaan, faktor tahun 2009 dan 2010.

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LIST OF ABBREVIATIONS

ALD	-	Asymmetric Laplace Distribution
ARDL	-	Autoregressive Distributed Lag
BRIC	-	Brazil, Russia, India And China
CPI	-	Consumer Price Index
DOLS	-	Dynamic Ordinary Least Squares
EU	-	European Union
FDI	-	Foreign Direct Investment
FIR	-	Financial Intelligence Report
FMOLS	-	Fully Modified Ordinary Least Squares
G20	-	Group-20
GDP	-	Gross Domestic Product
GLS	-	Generalized Least Squares
GMM	-	Generalized Method Of Moment
GNI	-	Gross National Income
HAC	-	Heteroskedasticity And Serial Correlation
HC	-	Heteroskedasticity Consistent
ISIC	-	International Standard Industrial Classification
NAFTA	-	North American Free Trade Agreement
NFE	-	Nonlinear Fixed Effects
NME	-	Nonlinear Mixed Effects
NPL	-	Non-Performing Loans
OECD	-	Organisation For Economic Co-Operation And Development
OLS	-	Ordinary Least Squares
QML	-	Quasi Maximum Likelihood
RENB	-	Random Effects Negative Binomial
RPV	-	Relative Price Variability
SDPDM	-	Spatial Dynamic Panel Data Model
SGMM	-	System Generalized Method of Moments
SVAR	-	Structural Vector Autoregressive
UN	-	United Nations
VAR	-	Vector Autoregressive
VECM	-	Vector Error Correction Model
WDI	-	World Development Indicator

CHAPTER 1

INTRODUCTION

1.1 Statistical Modelling

Humanity has long recognized that information, that is neglected and allowed to lapse without proper systematic treatment represents untold loss in potential. Ancient civilisations kept records that enabled them to study historical data and disseminate valuable insights derived from scrutinizing information. The cuneiform for instance, was used in 3500 BC by the Sumerians in the Mesopotamian civilisation to keep records of items and transactions. This systematic approach in documenting economic activities had enabled the society to build upon progress made by their predecessors and continue to thrive and turn into one of the most successful civilisations in the ancient world. This historical evidence reflecting the fact that society's ability to store information and learn from history is crucial for progress, finds its parallel in the modern world. The Cancer Moonshot program for instance, which was launched in the Unites States (U.S.) aimed to generate great strides by halving the time it takes to reach the next milestone in cancer research. This would only be possible by building upon existing data which documents patient's responses to specific treatments. Indeed, this systematic treatment of data gathered from hospitals, research institutions and public health authorities and integrated into a comprehensive system has the potential to ultimately develop cure for cancer (Lebied, 2018).

Abundance of data coupled with advancements in computational technology has enabled data scientists and statisticians to discern underlying relational nexus from anecdotal correlations. Although modern statistics in its early form which involves systematic collection of demographic and economic data could be traced back to the 18^{th} century, it was not until the early 19^{th} century that formal considerations of probability and statistical inference became the forefront of statistical practice. This formalisation of probability model into statistical investigation finds its applications in physical science though the study of thermodynamics and statistical mechanics as well as in social sciences though the study of econometrics–an integrated study of economic data and statistical modelling. A general regression model that illustrates modelling of economic data may be presented by a univariate regressions modelling as found in Pollock (2014). The model consists of a dependent variable also known as regressand denoted as y_i where in the case of the model presented by Pollock (2014) it is expenditure. The independent variable or also known as the regressor x_i is income. The model consists of an intercept parameter donated as β_0 and a slope parameter denoted as β_1 and a random variable, ε_i. The subscript i represents the i^{th} individual. Such specification attempts to describe the underlying structure that describes the relationship between an individual's income and consumption expenditure. The parameter β_1 captures the induced change in expenditure, y_i as income, x_i changes by one unit. The parameter β_0 is the intercept term that describes the portion of expenditure that is autonomously determined while ε_i is the random structure of the model which is not captured by regressor x_i. Such model allows statisticians to infer on individual's expenditure pattern based on their income. This inference holds given that certain assumptions on the random variable ε_i are met. These assumptions are:

(a) ε_i are independently distributed.

(b) Expected value of random variables, $E(\varepsilon) = 0$.

(c) Constant variance of error terms, $V(\varepsilon_i) = E(\varepsilon_i^2) = \sigma^2$.

These assumptions ensure that sound inferences could be made on the relationship between regressor and regressand. For instance, given that assumptions (i), (ii) and (iii) are met, a statistician may infer that a unit increase in individual's income will induce a β_1 increase in an individual's expenditure.

Notice that the model specified above captures the underlying structure between regressor and regressand by observing structural innovations across individuals. Such model is referred to as cross-sectional model. Another way of describing structural nexus between income and expenditure would be by expressing the regressor as y_t to represent expenditure, x_t to represent income, β_0 and β_1 are the analogous parameters and ε_t is random variable. The subscript t represents period of observation. A crucial difference between the two specification is that the former captures structural relationship across individuals while the latter captures structural relationship across time for one individual. As such, inference made by specification in the former model may be generalized for all individuals in the given sample. Meanwhile, inference made by the latter model which is known as time series model may only apply to the one individual estimated by the model. The time series model is useful however, in predicting how changes in an individual's future income may affect his expenditure pattern in the future.

It is clear that both aforementioned models are useful in specific settings, while inheriting certain drawbacks. A pure cross-sectional model is unable to be used to predict future movements of regressand as it is only able to capture heterogeneity across individuals. Meanwhile, a pure time series model may not be generalized to infer on other individuals as it only captures heterogeneity across time dimension. It is against this backdrop, that the first panel data method was introduced by Airy in 1861 in their analysis of human hereditary (Nerlove, 2002). A panel data model is defined as a statistical model that involves observations of multiple cross sections over time. The model is estimated by taking into account structural nexus across individuals and time dimension. As noted by Nerlove (2002), such specification yields at least three benefits. First, it allows greater utilisation of data. Second, since panel data are commonly not as aggregated as pure times series data, panel data analysis allows greater excursion into the dynamics between variables in the model. Third, panel data allows a statistician to explicitly model the random variable itself as a component common to all individuals at a specific period and as a component that is invariable across time. This is a crucial advantage as random variables are often argued to include the effects of omitted variable and that they may be correlated to some of the included regressors in non-panel model setup. Thus, scientists are able to systematically study individual heterogeneity, in ways which are not possible in pure cross section and time series model specifications.

1.2 Industrial Output

This section lays out the justification for considering industrial output as a measurement of aggregate productive capacity of countries. In particular, it will justify the use of a specific definition of industrial output as outlined by the United Nations. Additionally, all of the data cited in this dissertation are obtained from World Bank's data base. This ensures consistency in measurement and data definition.

Earlier works in macroeconomic modelling focused on Gross Domestic Product (GDP) as a proxy for economic growth. Technically, GDP is defined as the total value of production of all resident producing units of a country in a specified period, before deducting allowances for consumption of fixed capital (Department of Statistics Malaysia, 2019). The use of GDP has proved sufficient as evident in the vast body of macroeconomic models. However, there are some drawbacks associated with adopting GDP as a measure of national output. As modern economies transformed and underwent significant structural changes, GDP has become increasingly broad and surprisingly inaccurate. This is evident as countries are not immune to constant revisions to GDP figures as new methods and elements are introduced in its calculation. This fact coupled with the objective of this research, which among others includes investigating the determinants of industrial economic activities, it would be reasonable to instead, use a proxy other than GDP.

The modern economy is no longer dominated by the production of physical items as found in the agriculture, manufacturing and mining industries. As an economy transitions from a lower income to a higher income economy, it would be less dependent on the production of physical items and more dependent on non-intangible services industries. In fact, this trend holds true at a more general level where world production in manufacturing is being supplanted by services industries. This shift in structural composition of world output is reflected in Figure 1.1.

Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources. The origin of value added is determined by the International Standard Industrial Classification (ISIC), Revision 4, which is a document released by the United Nations. The value added of the manufacturing industries for instance, would include the value of edible palm oil produced by cooking oil manufacturers less the value of crude palm oil bought from palm oil extraction producers. Similar definition applies in the services industry. Figure 1.1 highlights several interesting features. First, from 1997 up to 2016, services value added as a percentage of GDP ranges from 60% to 65% while manufacturing value added as a percentage of GDP ranges from 15% to 18%. Second, there is an upward trend for services value added and a downward trend for manufacturing value added. However, it is worth noting that the variability of services value added is greater than that of the manufacturing industries. This observation stems from the fact that services value added includes a diverse set of industries ranging from financial and banking industry to real estate services. Technically, services value added includes the output value of industries listed under the range of division 50 to 99 in the United Nation's (UN) ISIC Revision 4. Meanwhile, manufacturing value added is composed of a relatively limited scope of industries ranging from division 15 to 37 in the ISIC (United Nations, 2008).

Another salient feature of Figure 1.1 is that there seems to be a repelling factor between manufacturing and services value added. As manufacturing value added as a percentage of GDP declined from 17.5% in 1997 to 15.8% in 2003, services value added as a percentage of GDP increased from 61.7% in 1997 to 64.0% in 2003. Similar repelling pattern could be seen from 2003 to 2010, after which the two series seemed to briefly move in sync before continuing a repelling pattern. This negative relationship between manufacturing and services as a percentage of GDP stems from the fact that increased prevalence of one sector is bound to lead to decline in the other sectors of the economy when expressed as a component of GDP. What this trade-off depicted in Figure 1.1 signifies is the structural change of the economy, where as aggregate output increases, the economy will increasingly be composed of services i.e. the third sector of the economy.

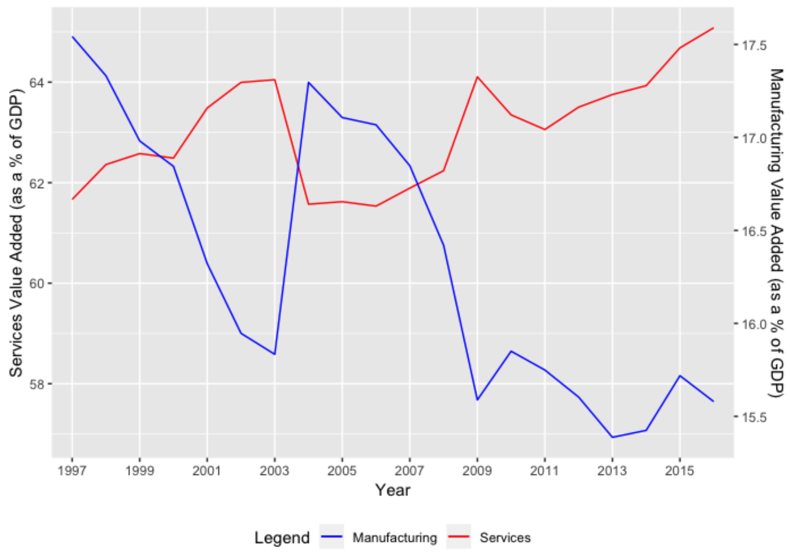

Figure 1.1 Services and Manufacturing Value Added (as a % of GDP)

Although at a superficial level, it may be argued that in order to capture economic activities more accurately, a researcher would take into account of value added in services, considering the extent of its contribution to GDP. However, this argument would ignore that composition of services. Note that this research utilizes the standard ISIC definition of services. As such, it would include value added provided by governments such as financial services by central banks (division 64: 6411), public administration and defence (division 84), education (division 85) and health services (division 86). Government expenditure may either be is procyclical, where government increases expenditure during economic boom and reduces expenditure during recession, or countercyclical where government reduces expenditure during economic boom and increases expenditure during recession. Which type of government expenditure pattern persists in the economy depends on public policy ideology, which in turn varies by countries. Hence it follows that value added generated by public sector's activities include these variabilities. Since it is not the intention of this research to investigate the determinants of procyclicality and countercyclicality of value added activities, we argue against using services value added as a proxy.

Another reason against using services value added to capture economic productivity is the nature of activities in the services industries. Among the items included in ISIC category of services is creative arts industries such as theatrical performances, opera, concerts, dance and other on-stage performances (division 90:9000). Although these are indeed value-creating activities and should be recognized, scientific investigation on aggregate output that includes such activities has the potential to inflate the actual productive potential of the economy. Since this research intends to focus on industrial production, it would be inaccurate to even consider GDP as it includes services value added which in turn includes activities such as those specified in division 90 of UN's ISIC specification (United Nations, 2008).

The obvious alternative consideration in capturing industrial economic activities is industrial value added. The manufacturing data (division 15 to 37) presented in Figure 1.1 is meant as an example to juxtapose against services to serve as a backdrop for the value added composition of economies. However, industrial value added definition may be extended to capture a broader range of industrial activities. This would enable this research to cater to a broader scope of the industrial sector, while alienating the direct impact of public policies and other value-creating but non-productive activities. Following World Bank's categorization of industrial output, this dissertation considers divisions 10 to 45 of ISIC's classification, which includes manufacturing (ISIC divisions 15 to 37). It also comprises value added in mining, manufacturing (also reported as a separate subgroup), construction, electricity, water, and gas (United Nations, 2008).

1.3 Key Macroeconomic Variables' Interaction with Industrial Output

This section provides preliminary justification for the regressors considered in this dissertation. Data trends are examined which will be used to form arguments presented in section 1.4. Discussions in sections 2.3 and 3.2 will provide more justification for the regressors.

Formal investigation on industrial production could be traced back to a public funded research initiated by Burns (1934), which studied trends of industrial production in the U.S. since 1870. The research documented trends exhibited by various industries in the U.S. while attempting to form generalizations on industrial patterns. Burns (1934) posited that industrial growth undergoes a process he termed as retardation. The retardation of industrial growth refers to a phenomenon where industrial output tends to increase and accelerate in the early years of industrialization. After a certain period of accelerated growth, which varies according to different industries, industrial output increases at a decelerated pace before undergoing a slow decline. Within the context of inter-industry linkages, Burns (1934) attributed this retardation process to technological progress in a competing industry.

Scientific investigations on industrial production started in the 1930s through the works of such pioneers as Simon S. Kuznets (Gold, 1964). Since then, numerous researches have been conducted to better understand the behavior of industrial production. Unlike governments, of which productivity behavior is dependent on rather predictable factors as elections, economic cycle and budget constraints, industrial output exhibits greater variability. Moreover, establishing a comprehensive model that explains industrial output behavior has been at the forefront of early economic modelling works. A basic model that explains aggregate industrial production may be found in Boschini (2006). The model specifies a two sector economy one of which is a traditional low skilled sector and the other is a high skill intensive sector. In this simple two sector economy, it could be inferred that variations in aggregate industrial output is influenced by investment expenditure and government expenditure. Extending this explanation to empirical evidence, however, is non-trivial. Figure 1.2 reveals that both industrial output and government consumption at constant 2010 US$ exhibit upward trends. In part, this could be driven by increase in demand which is mainly attributed to population growth. This research however is mainly interested in investigating the determinants of industrial output. Despite the theoretical model found in Boschini (2006) positing a relationship between government consumption with industrial output, we find evidence that the two series do not always move in line with each other. In 2009 for instance, despite increment in government consumption, world industrial output decreased. Moreover, despite exhibiting a relatively constant growth rate from 2000 to 2008, industrial output grew at a decelerated pace during the same period. Thus, this superficial examination of data indicate that at the very least, that the relationship between industrial output and government consumption are not robust. Further investigation between the two series is warranted. Note that both industrial output and government consumption are measured at constant 2010 US$ to eliminate the effects of changes in price levels.

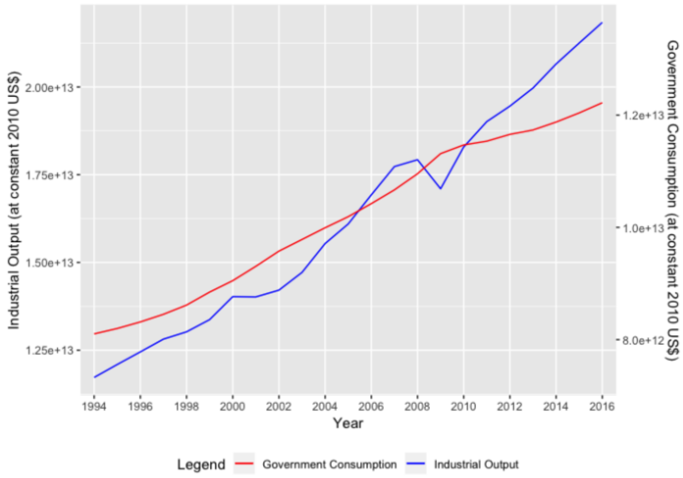

Figure 1.2 Government Consumption and Industrial Output

Extending similar arguments for other determinants of industrial output, it could be demonstrated empirically that a systematic examination is in order. As will be discussed in chapter 2 in greater detail, industrial output could be theoretically explained by household consumption, inflation rate, interest rate, money supply and trade openness.

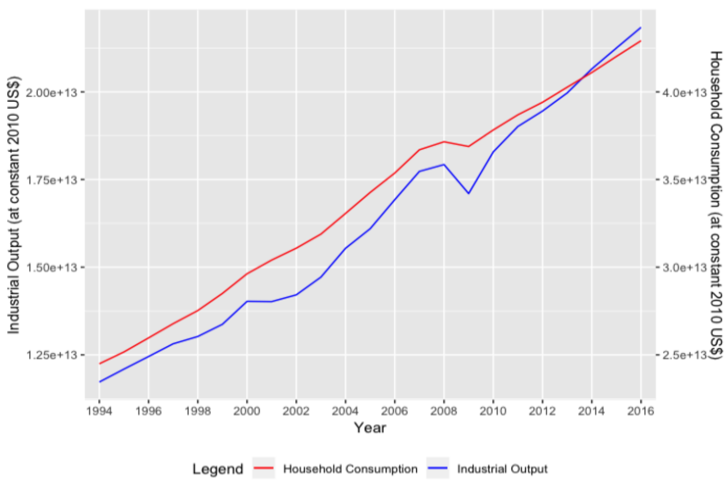

Figure 1.3 Household Consumption and Industrial Output

Similar to government consumption, household consumption at constant 2010 US$ exhibits an upward trend, generally moving with industrial output, as seen in Figure 1.3. It could be argued that household consumption is a particularly influential macroeconomic determinant of industrial output as it represents the demand factor in the economy. A strong demand for consumption of industrial products from household would stimulate industrial output which represents supply in the macroeconomic setting (Solow, 1956). A systematic study on the relationship between household consumption and industrial output is therefore justified, on the basis on data observation and argument. Note household consumption is measured at constant 2010 US$ to eliminate the effects of changes in price levels.

Theoretical models such as those in Pokrovskii and Schinckus (2016) shows that there is a connection between money and output. Growth in money supply increases liquidity at the aggregate level. This increased liquidity stimulates business activities and expands aggregate production. Moreover, empirical investigations on national level reveal a bidirectional causal relationship between money supply and output (Wang et al., 2014). Thus, increase in money supply stimulates output growth which in turn further stimulates growth in money. A superficial examination of money supply and industrial output data as in Figure 1.4 however raises the extent of which this relationship holds.

Generally, both money supply and industrial output exhibit upward trends. However, closer inspection of data reveals several points where the two series seem to move out of line from each other. For instance, in spite of increase in money supply in 2009, industrial output declined. In 1996, industrial output continued on an upward trend despite fall in money supply. These observations raises questions on the robustness of the relationship between money supply and industrial output, particularly on a global and regional level. Note that in this discussion, we observed money supply as a percentage of GDP. This is merely to provide a context in out discussion on the relationship between industrial output and money. Analytical procedures in chapter 4 however, will utilize money supply expressed in domestic currencies.

Figure 1.4 Money Supply and Industrial Output

Inflation rate is defined as increase in general price level, measured by the consumer price index (CPI). According to the monetarist view, inflation is related to quantity of money. The relationship between money and price level could be described by the quantity theory of money (Pokrovskii and Schinckus, 2016). The theory states that the product of money supply or the quantity of money in circulation denoted by M and the velocity of money denoted by V which measures the number of times a unit of money is used for transaction in a specified time period is proportional to the general price level denoted by P, which is captured by CPI and aggregate income level denoted by Y. The quantity theory of money posits a positive relationship between money supply and general price level. Hence, an increase in money supply, M would induce increase in general price level, P, which technically defines inflation. However, this monetarist view of ascribing inflation solely to money supply is simplistic. In reality, inflation is influenced by a host of other factors. This includes increase in cost of intermediate goods, increase in oil price, increase in demand which in turn may be due to increase in income or population. Thus, with regard to its relationship with industrial output, the quantity of money in circulation could be decoupled from inflation rate. Therefore, it is justifiable to examine the effects of inflation on industrial output alongside money supply.

Figure 1.5 Inflation Rate and Industrial Output

Unlike industrial output, inflation rate exhibits greater variability. One obvious reason is that inflation rate is measured as percentage change over year, which is the definition of annual inflation. However, it is the intention of this research to show the effects of price changes on industrial output behaviour. For instance, inflation rate in 2001 is 3.99%, which is higher compared to inflation rate in 2000 which is 3.5%. This means that prices in 2001 increased at a higher rate compared to 2000. Concurrently, it could be observed in Figure 1.5 that industrial output fell in 2001. This decline in industrial output could be an effect of higher rate of general price level increment. It is in capturing these dynamics between industrial output and inflation that this research intends to achieve by including inflation rate in this dissertation's consideration.

Theoretical economic models posit that trade generally have a positive impact on national output growth. Grossman and Helpman (2018) for instance, showed in an equilibrium modelling that the aggregate output equilibrium for an open economy is higher than the aggregate output equilibrium for a closed economy. It is therefore straightforward to extend this model to our discussion of industrial output. Since industrial output is a vital component in aggregate output, it can be argued that Grossman and Helpman (2018) model implies that trade openness stimulates industrial output growth.

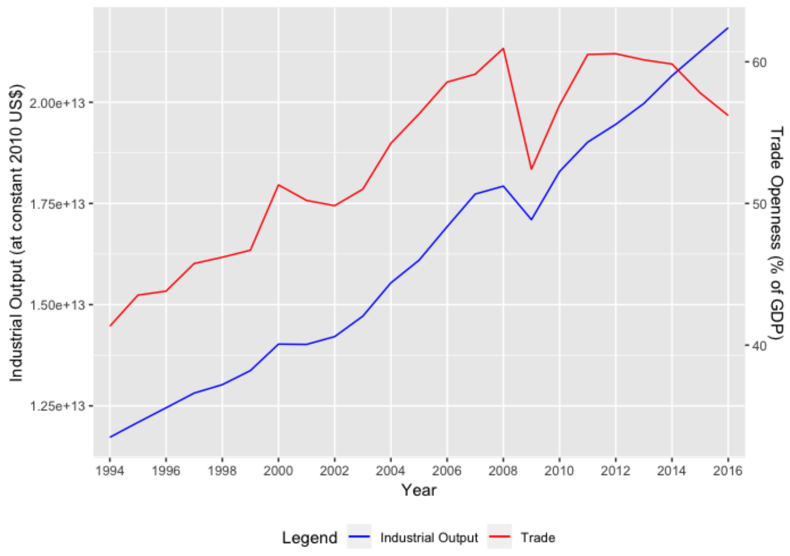

Figure 1.6 Trade and Industrial Output

In measuring the effects of trade on industrial output, it is useful to express total trade which includes imports and exports on expressed as a percentage of GDP, which concurrently is the definition of trade openness. This is because unlike net exports, trade openness measures prevalence of trade in aggregate economic activities. Exports contribute to national income and output. Imports contribute to the productive capacity of the economy in terms of intermediate goods which are utilized for domestic production. Thus, it could be argued that imports stimulates domestic output. Using trade openness instead of net exports therefore, allows a researcher to acknowledge the positive effects of both exports and imports on aggregate output and by extension, industrial output.

The relationship between industrial output and trade openness as depicted in Figure 1.6 indicate a general positive relationship as both series exhibit upward trends over the 1995 to 2017 period. The gravity of relationship between the two series could be seen in 2009 where trade openness fell sharply from 60.9% in 2008 to 52.4% in 2009. Concurrently, industrial output fell from US$179 trillion to US$171 trillion. Other salient spikes and downturns depicted in Figure 1.6 provide significant justification to further investigate the relationship between industrial output and trade openness.

Dia and Menna (2016) provided an update to the real business cycle model which describes the evolution of economic activities. Interest rates as found in traditional model posited to have a negative impact of aggregate output. As productive economic agents initiate or increase production, they would have to tap the financial sector, i.e. banks. The financial sector has an intermediary role in channelling funds from those who have excess resource to those who have productive capacity. In return for performing this intermediary role, banks charge interests in order to make profit, as well as to incentivise lending. From the perspective of productive economic agents however, interest rate charged by banks are considered as costs. Thus, theoretically there would be a negative relationship between interest rate and industrial output.

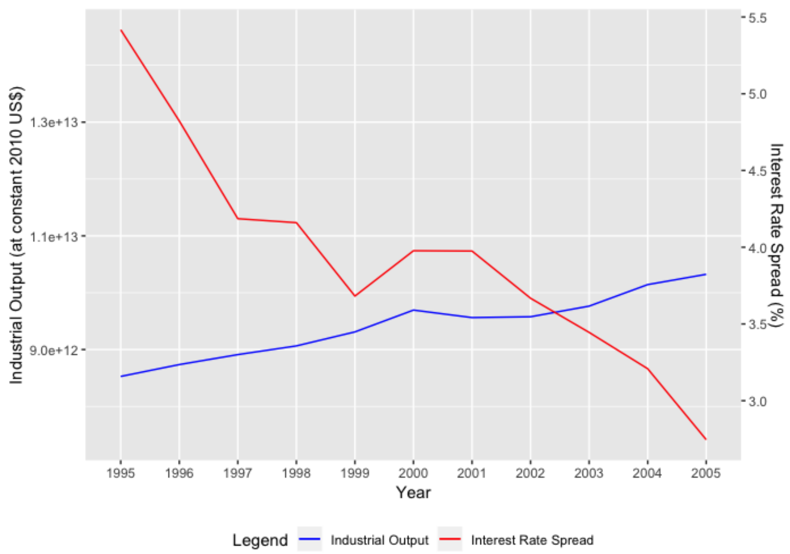

Figure 1.7 Interest Rate Spread and Industrial Output

For the purpose of framing a context of discussion, consider the interest rate spread and aggregate industrial output in the Organisation for Economic Co-operation and Development (OECD) countries as depicted in Figure 1.7. Within the ten year period from 1995 to 2005, interest rate spread in OECD countries, the most industrialized countries in the world fell from 5.4% to 2.7%. Industrial output at constant 2010 US$ on the other hand, increased from US$8.5 trillion to US$10.3 trillion. Thus, it could be observed that there is a general negative relationship between industrial output and interest rate. Delving further on the relationship between these two series in a systematic approach is therefore justified.

For every key determinants, some theoretical justifications are provided. Section 3.2 will expound on this. At this juncture however, based on the preliminary data observations of key variables, it is clear that some relationship exists between industrial output with household consumption, government consumption, money supply, inflation, interest rate and trade openness. Trends of household consumption, government consumption, money supply and trade seem to move in line with trend of industrial output. Meanwhile, the trends of inflation and interest rate seem to move against the trend of industrial output. These observations provide justification for statistically examining the underlying relationship between aforementioned determinants with industrial output.

Another important consideration in discussing the interaction between the key determinants with industrial output is the income levels of countries. Consider the relationship between household consumption and aggregate output where it is theoretically expected to be positive, as will be discussed in chapter 2 of this dissertation. This relationship however, may not be generalizable to all countries in the global economy. For instance, while the supposition may be true for high income countries, it may not hold for low income countries. Thus, the direction of relationship between industrial output with its determinants may not be the same due to existence of heterogeneity in the data according country's income levels. It would be scientifically prudent therefore to assume that the parameters of panel data models would be different according the different categories of income levels.

1.4 Problem Statement

Section 1.2 has dealt with the reason for adopting industrial value added as a measurement of economic productivity while section 1.3 explored key macroeconomic data and provided theoretical argument for the relationship between aforementioned variables with industrial output. At this juncture, it is clear that household consumption, government consumption, money supply, inflation rate, trade openness and interest rate are key macroeconomic determinants of industrial output. The theoretical positions presented in section 1.3 is supported by empirical evidence.

For instance, increase in government expenditure in the U.S. has been found to increase aggregate output in a panel data study by Atems (2019). With regard to household consumption, Sun and Deng (2013) showed in a provincial study, that output growth is positively related to household consumption growth. Moreover, this relationship is said to be persistent in the long-run. Lo Turco et al. (2018) on the other hand, concluded that a there is a non-negligible impact of money supply on output growth. Baharumshah et al. (2016) showed in a panel data empirical investigation that inflation tends to negatively impact output growth in non-inflationary crisis countries. Simple economic models such as one presented by Mertens (2010) showed that interest rates are negatively related to output growth. Empirical evidence in support of this view however, is lacking. A panel data empirical study by Sikder et al. (2019) showed that trade openness has a long-run and positive relationship with aggregate output.

Despite the fact that preliminary inferences is backed by observational evidence, there is ambiguity on the collective effect of the identified determinants of industrial output. While it may be clear that interest rate is negatively related with industrial output based on Figure 1.7, this relationship may not hold if the interaction between industrial output with other determinants like trade and inflation rate is introduced. The effect of interest rate on industrial output may be amplified of may be subdued due to the effects of inflation rate for instance. A systematic study that determines the underlying relationship is therefore important.

Another point that provides justification for a panel data study of industrial output is the nature of relationship between macroeconomic variables may be different according to levels of income. For instance, it was found that the estimated coefficient for inflation in emerging economies which serve as a proxy for middle income economies differed significantly than the coefficient in industrialized economies which serve as proxy for high income economies. This is to be expected since the respond variable for this study i.e. industrial output would behave differently according to income level of the economy. Estimating coefficients for industrial output determinants that can represent the various income levels in the global economy would therefore enable researchers and policy makers to appropriately handle its determinants. Hence, there is a need to investigate the relationship between industrial output and its determinants, with respect to the income levels of countries. This will ultimately contribute to the gap in the literature where there is yet a comprehensive panel data study on industrial output, while accounting for income levels of countries in the global economy data set.

In panel data modelling, heteroskedasticity is often a problem. This is especially true when the cross section components are of different sizes (Mátyás and Sevestre, 2008). Even upon segregating the complete data set to four sub-data sets according to its respective income levels, differences in actual industrial output exists within the sub-data sets. This would result in heteroskedasticity in disturbance terms. It would therefore be necessary to properly develop panel data models for industrial output in order to obtain reliable results and avoid misleading conclusions which in turn could prove disastrous in terms of policy making.

1.5 Research Objectives

This research aims to fill the gap in the literature in the field of applied panel data modelling. Panel data modelling is a substantially useful area that can be applied in various fields of scientific studies. In economics, panel data has been widely used to model many economic problems ranging from economic growth to political financing. However, this research focusses on industrial output modelling against the backdrop of the global economy. Acknowledging the problem of heterogeneity in panel data modelling, this research further aims to contribute to the literature in investigating industrial output behaviour in relation to income status of economies, while ensuring principles of statistically sound modelling are met.

In line with the overarching goal of this research, following are the objectives of this research:

(a) To model the global economy's industrial output using pooled, fixed effects, time fixed effects or random effects panel data model.

(b) To model the industrial output for low income economies, lower middle income economies, upper middle income economies and high income economies which are all subset of the global economy data set using pooled, fixed effects, time fixed effects or random effects panel data model.

(c) To adopt robust methods in estimating the standard errors of chosen panel data models.

(d) To compare efficiency of panel data models under different robust standard error estimation.

(e) To compare the performance of panel data models under different robust standard error estimation.

1.6 Significance of Study

The contributions of this research are fourfold. First, it provides a comprehensive panel data model that describes industrial output for the global economy. As highlighted in section 1.4, there is yet a model that describes industrial output, particularly one that acknowledges heterogeneity of countries with different income levels. Second, this research applies up to five heteroskedasticity consistent tests to determine significance of individual determinants in the model. Since heteroskedasticity is a common problem faced in panel data models, this research highlights the various methods that can be adopted in addressing this issue, which in turn ensures that correct inferences can be made. Third, this dissertation intends to highlight changes in performance of panel data models under different robust standard error estimation methods. This will provide valuable insight into the exact impact of heteroskedastic and serially correlated errors on panel data models. Fourth, this research contributes to the literature in terms of its policy recommendations. Since the inferences made will be based on sound statistical modelling, this research provides assurance to policy makers that recommendations derived from this research are based on sound scientific methods which minimizes possibility of error in judgement.

1.7 Scope of Study

In the interest of forming a tractable scientific study, it is necessary to define the scope of this research. In line with the objectives outlined in section 1.5, this study only considers pooled, fixed effects, fixed time effects and random effects panel data model in describing the industrial output. The appropriate model is determined by a series of relevant tests. Once the appropriate model has been established, the model is subjected to several diagnostic tests to determine its validity. This research then addresses the problem identified in the diagnosis by estimating the relevant parameters using appropriate methods as found in the literature. This research does not attempt to develop new methods to address problems faced in the panel data models. Rather, the efficiencies of existing methods are investigated in its application to industrial output panel data models.

1.8 Limitation of Study

Despite efforts to minimize lapses in methods and judgements, this research faces several limitations in fulfilling its objectives. This research utilizes data from a single, reliable source i.e. the World Bank's World Development Indicator (WDI) databank. This minimizes possible measurement errors that may arise had data were obtained from multiple sources. Additionally, this would ease replication of the results obtained in this research. However, a drawback from relying from a single data source is that several data points were not able to be obtained. Some cross sections i.e. countries had to be eliminated from the panel data set. This is due to the unavailability of observations for some variables considered. In the interest of having a clean data set without the need for interpolation for missing observations, this dissertation eliminates the entire cross section. As a result, only 96 countries in total are deemed sufficient for further analysis.

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