AN AHP-BASED COMPOSITE INDEX FOR SECTOR PRIORITIZATION

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ABSTRACT

Economic sectors are highly interdependent, allowing them to promote sustainable development and inclusive growth by generating positive spillover effects from small investments in the economy. However, this interdependent nature can also generate negative spillover effects that lead to widespread inoperability and unemployment. While interdependence and the problem of scarce resources have led to the development of multiple sector prioritization tools, none of these tools have been able to wholly measure sector significance based on its multiple dimensions. Hence, this paper develops a composite sector prioritization index that identifies the key sectors based on five criteria of sector significance: degree of influence, structural significance, degree of interconnectedness, dependence on domestic economy, and contribution to risk of inoperability. The index is constructed using the Analytical Hierarchy Process, which shows the economy's priorities and primary concerns in order to aid policymakers in

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investing in sectors that would generate the highest positive spillover effects to the economy. A case study from the Philippines is considered and the results show that much of the economy's resources must be allocated towards the manufacturing, trade, and private services sectors.

Keywords: Input-Output modelling, Analytic Hierarchy Process, sector prioritization, sector interdependence

1. Introduction

Sustainable development and inclusive growth have increasingly been the central goals of many world economies. The rising trend towards sustainability stems from the shift towards achieving the "economic, environmental, and social dimensions of development" without endangering future potential development (Organisation for Co-operation and Development, 2011). Inclusive growth, on the other hand, has been increasingly popular as nations have seen the importance of striving for economic prosperity that can be felt by its individual members. As one of the United Nations' Sustainable Development Goals, sustainable and inclusive economic growth promotes economic prosperity as well as improvements in individual well-being, stable employment, and employment opportunities (Organisation for Co-operation and Development, 2011). The priority given to these goals highlights the importance of economic sectors because of their contribution to inclusive growth, development, and economic activity.

Economic sectors serve as the cogs of the economic machinery, each possessing a unique role in the overall development of the economy while also working together to produce raw materials and intermediate outputs for other sectors and consumers to use. Economic sectors play a large role in generating output for each country and are instrumental in providing a livelihood for its members. Additionally, economic sectors greatly impact the overall state of the economy. Because economies consist of sectors that are naturally interdependent, a negative or positive change in one sector can cascade and cause a corresponding negative or positive impact in other sectors, thus affecting the entire economy (Dejuán, Lenzen, & Cadarso, 2017). This means that while sector interdependence can allow small investments in one sector to generate positive spillover effects such as an increase in production level, income, and employment opportunities, this relationship can lead to negative spillover effects as well.

The interconnectedness of economic sectors can thus hamper the economy's ability to achieve growth and development. The initial impact experienced by one sector from negative exogenous shocks, such as disasters, can cascade to other sectors that were previously unaffected by said shocks. This means that if one sector experiences a sudden loss in production level, the sectors that depend on it as consumers and producers will experience losses from this as well (Resurreccion & Santos, 2012a). The compounded impact then impedes the economy's overall production, which in turn degrades individual welfare as negative shocks or production losses increase unemployment and poverty incidence.

There is also the problem of scarce resources, which gives rise to the need for efficient resource allocation in order to minimize the potential losses and maximize the potential gains of the economy. Hence, countries must aim to understand the underlying structure and system of their respective economies in order to strategically allocate resources for each sector. This highlights the importance of understanding the specific roles and characteristics of each sector, as well as identifying the economy's most crucial sectors.

Recently, there has been a growing interest in identifying key economic sectors using various measures developed from input-output (I-O) modelling. Input-output modelling's ability to account for the interrelationships among sectors makes it a powerful tool in studying the structure of the economy (Hewings, 1982). The studies include the use of forward and backward linkages to measure each sector's demand- and supply-side dependence on other sectors for the Bangladesh, Indian, and Japanese economies (Alauddin, 1986, Dhawan & Saxena, 1992, Zuhdi, 2017b). The power of dispersion index, which measures sector influence, and the sensitivity of dispersion index, which measures sector sensitivity to exogenous changes, were also used as a basis for sector ranks in the Japanese economy and growth factor decomposition, which was used by Ballester et al. (2013) to identify the key sector in the Philippine economy from 1961 to 2006 (Zuhdi, 2017a). However, these studies were only able to rank sector importance based on individual sector significance measures. Hence, they were unable to wholly account for the various criteria that collectively contribute to a sector's overall significance to the economy.

There has also been a growing field of literature that develops sector prioritization tools for resource allocation decisions. These include Tsekeris's (2017) work, where he used network analysis measures such as degree centrality (sector interactions) and closeness centrality (economic distance) for the Greek economy, and several studies that have been proposed to base the allocation of resources on a sector's sensitivity to disruptions by developing risk-based sector prioritization techniques. These include Barker and Santos' (2010) work which uses Lian and Haimes' (2006) dynamic inoperability input-output model to identify the sectors that are highly sensitive to inventory delays, and Resurreccion and Santos' (2012b) work which uses the dynamic cross-prioritization plot to determine key sectors based on their sensitivity to risk and their role in meeting the primary goals of the economy.

While there have been numerous studies which aim to identify the key sectors in an economy, the previous literature lacks studies that focus on developing composite indices that capture various dimensions of sector importance. One of the key studies that developed a composite index is that of Yu et al. (2014), who introduced the vulnerability index, a risk-based sector prioritization tool that identifies critical sectors based on three aspects that contribute to vulnerability: economic impact, sector size, and the propagation length of each sector. However, since this study was solely focused on vulnerability and post-disaster techniques, its index only ranked sectors in terms of measures that contribute to these issues. Thus, there is still a need to develop a multi-dimensional composite index composed of various measures (or criteria) that collectively contribute to the overall significance of a sector to the economy.

Hence, this study fills the research gap by developing a composite multi-criterion index that measures overall sector significance. In addition, this study introduces the use of the

Analytic Hierarchy Process as a weighting procedure for the different index components based on experts' assessments rather than choosing weights arbitrarily.

Yu et al. (2014) state that a systematic approach to weighing each of the index components, such as Saaty's Analytic Hierarchy Process (AHP), is needed to better mirror the economy's preference assignments of the sector significance criteria. For these reasons, the construction of the composite index may benefit various stakeholders, especially policymakers, in identifying which sectors to prioritize in policymaking and resource allocation decisions.

This methodology is widely used in a variety of fields and has been increasingly used in the development of various composite indices. This systematic approach to generating weights is widely used in a variety of studies including industrial engineering decision making, supplier selection problems, SWOT analysis, research and development project prioritization, human capital indicator rankings, and economic studies such as I-O modelling and forecasting the foreign exchange rates and the recovery of the United States' economy (Triantaphyllou & Mann, 1995; Nydick & Hill, 1992; Barbarosoglu & Yazgac, 1997; Liu & Hai, 2005; Kurttila, Kangas, & Kajanus, 2000; Silva, Belderrain & Pantoja, 2010; Abdullah, Jaafar & Che Taib, 2013; Saaty & Vargas, 1979; Saaty, 2010). The AHP has been increasingly used in the development of composite indices such as the environmental performance index (Dedeke, 2013). It has been widely used by corporations and institutions in measuring the impact of their policy decisions on the environment, the cyclical economic performance indices (Niemira, 2001). It has also been used as an alternative to traditional-NBER[1] methods, the composite industry sustainability performance index that accounts for the different dimensions of sustainability such as its social and economic aspects, and the disaster-resilience index for local communities in the Philippines (Pandian, Jawahar & Nachiappan, 2013; Orencio & Fujii, 2013). Overall, these studies illustrate the versatility and sophistication of the AHP framework used in the study. This study is set apart from the growing pool of related literature because it is the first or one of the first composite indices that uses AHP in measuring multi-criterion sector significance.

Given this, the study develops a composite multi-criterion index through AHP to identify the critical sectors to prioritize in an economy. The index ranges between 0 and 1, where higher values imply that the sector has a larger degree of contribution and vulnerability to risks. These higher value sectors must be given more priority in resource allocation decisions.

The composite index analyzes the sector's role and relative importance in an economy through five criteria of sector significance, namely the power of dispersion index, sector size, average propagation length, sectoral purchase coefficient, and inoperability multiplier. First, the power of dispersion index measures how a change in one sector's final demand impacts other sectors. This measures the sector's relative influence over other sectors in the economy. Thus, sectors with higher power of dispersion indices must be given more priority (Zuhdi, 2017b). Second, the sector size measures the structural significance of a sector with respect to the entire economy, which in turn contributes to

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its overall significance (Yu et al., 2014). Third, the average propagation length measures a sector's degree of interconnectedness as both a producer for and a consumer of other sectors. Higher degrees of interconnectedness will indicate that a sector plays a relatively larger role in the overall economy (Yu et al., 2014). Fourth, the sectoral purchase coefficient measures a sector's dependence on the domestic economy. Sectors with higher sectoral purchase coefficients are given more importance as they are more dependent on the inputs of domestic sectors for their production. Thus, these sectors are more vulnerable to domestic shocks that will impede the production of the sectors they are dependent on (Resurreccion & Santos, 2012a). This, in turn, will also contribute to a greater scale of economic loss and inoperability in the economy. Last, the inoperability multiplier measures a sector's contribution to the economy's risk of inoperability. This contributes to sector significance because the additional exogenous shock experienced by the sector will lead to a higher degree of inoperability on the entire economy (Yu et al., 2014).

Because of these features, the composite index is considered a useful tool to aid policymakers in identifying which sectors to prioritize given the economy's varied priorities and preferences. The creation of this tool may benefit various stakeholders in their resource allocation decisions as it identifies the key economic sectors while accounting for a wider range of factors the economy may consider. Since this tool grants policymakers a broader view of an economy's various concerns, it allows them to determine which sectors are critically in need of investment and should be given the most priority.

The remainder of the paper is organized as follows. Section 2 presents the data used in the case study and the mathematical foundations of the sector significance criteria, which will serve as the components of the composite index. Section 3 presents the formulation of the composite index. Section 4 presents the case study where the index was used to identify the critical sectors in the Philippine economy. Lastly, Section 5 summarizes the paper and elaborates on the recommendations for future research.

2. Mathematical foundations

The I-O tables are used to generate the five criteria of sector significance mentioned earlier: (1) the power of dispersion index, which measures each sector's degree of influence, (2) the sector size, which measures each sector's structural significance, (3) the average propagation length, which measures each sector's number of inter-industry interactions, (4) the sectoral purchase coefficient, which measures each sector's dependence on the domestic economy, and (5) the inoperability multiplier, which measures each sector's contribution to the risk of inoperability caused by exogenous shocks. The mathematical foundations of these five criteria are demonstrated below.

2.1 Basic Leontief Input-Output model

The basic I-O model was first established by Leontief (1936) to illustrate the interdependent nature of economic sectors. This system of linear equations was developed to represent the interindustry transactions in the economy, where each sector produces homogeneous goods and services and uses a fixed amount of inputs in its production of outputs (Miller & Blair, 2009). This model is formally defined as:

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$$\mathbf{x} = \mathbf{Ax} + \mathbf{f}, \tag{1}$$

where $\mathbf{x}$ is the total output vector, $\mathbf{A}$ is the technical coefficients matrix with each element a_{ij} representing the proportion of sector j's input requirement contributed by sector i, and $\mathbf{f}$ is the final demand vector.

Alternatively, this can be expressed as:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f}, \tag{2}$$

where $(\mathbf{I} - \mathbf{A})^{-1}$ is commonly known as the Leontief Inverse Matrix.

2.2 Power of dispersion index

The power of dispersion index was established by Rasmussenís (1957) as a measure for the nature of inter-sectoral relationships. This measure is widely used in studying economic linkages and sector roles. Rasmussenís (1957 in Drejer, 2002) defines the power of dispersion index as the impact of an increase in the final demand of one sector on the output of the rest of the economy. This powerful measure determines a sector's degree of relative influence on the economy and is notably defined as:

$$p_i = \frac{\sum_{i=1}^{n}(\mathrm{I}-\mathrm{A})^{-1}{}_{ij}}{\frac{1}{n}\sum_{j=1}^{n}\sum_{i=1}^{n}(\mathrm{I}-\mathrm{A})^{-1}{}_{ij}}, \tag{3}$$

where $\sum_{i=1}^{n}(\mathrm{I}-\mathrm{A})^{-1}{}_{ij}$ represents the jth column sum of the Leontief inverse matrix and $\frac{1}{n}\sum_{j=1}^{n}\sum_{i=1}^{n}(\mathrm{I}-\mathrm{A})^{-1}{}_{ij}$ is the average of the total column sums of the Leontief inverse matrix.

2.3 Sector size

Yu et al. (2014) define each sector's size relative to the economy as:

$$z_i = \frac{x_i}{\sum_{i=1}^{n} x_i}, \tag{4}$$

where x_i is sector i's output level and z_i is a value that ranges from 0 to 1. Given this, z_i is defined as the ratio of sector i's output relative to the total output of the economy. A higher z_i indicates that sector i is relatively more important to the economy.

2.4 Average propagation length

The average propagation length (APL) was derived from the I-O model to measure the economic distance between two sectors while accounting for the size of the linkages between them (Dietzenbacher, Romero & Bosma, 2005). It was formally defined as "the average number of steps it takes to transmit a cost-push (demand-pull) from one sector to the other." Each element of the APL matrix is defined as follows:

$$s_{ij} = \begin{cases} int(v_{ij}) & \text{if } f_{ij} \geq a \\ 0 & \text{if } f_{ij} < a \end{cases}, \tag{5}$$

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where f_{ij} is the size of the linkage or the average of the cost-push (forward) and demand-pull (backward) effect from sector i to j, a is an arbitrary threshold level chosen to guarantee that only APLs of sectors with sufficiently large linkages are retained, and v_{ij} is the average number of industry interactions it takes to pass on a cost-push or demand-pull from sector i to j. v_{ij} is specifically defined as:

$$v_{ij} = \begin{cases} \frac{h_{ij}}{g_{ij}-\delta_{ij}} & \text{if } g_{ij} - \delta_{ij} > 0 \\ 0 & \text{if } g_{ij} - \delta_{ij} < 0 \end{cases}, \tag{6}$$

or:

$$v_{ij} = \begin{cases} \frac{k_{ij}}{l_{ij}-\delta_{ij}} & \text{if } l_{ij} - \delta_{ij} > 0 \\ 0 & \text{if } l_{ij} - \delta_{ij} < 0 \end{cases}, \tag{7}$$

where h_{ij} is an element from the matrix $\mathbf{H} = \mathbf{G}(\mathbf{G} - \mathbf{I})$, $\mathbf{G}$ is the Ghosh inverse matrix – which measures the change in output as a result of a change in primary costs, $\mathbf{I}$ is the Identity matrix, g_{ij} is an element of the Ghosh inverse matrix, δ_{ij} is the Kronecker delta which is equal to 1 if $i = j$ and equal to 0 if $i \neq j$, k_{ij} is an element from the matrix $\mathbf{K} = \mathbf{L}(\mathbf{L} - \mathbf{I})$ where $\mathbf{L}$ is the Leontief inverse matrix $(\mathbf{I} - \mathbf{A})^{-\mathbf{1}}$, and l_{ij} is an element of the Leontief inverse matrix. By definition, Equations 6 and 7 yield the same matrix.

Lastly, f_{ij} represents each element of the $\mathbf{F}$ matrix, which is defined as:

$$\mathbf{F} = \frac{1}{2[(\mathbf{L}-\mathbf{I}) + (\mathbf{G}-\mathbf{I})]}, \tag{8}$$

where $\mathbf{L} - \mathbf{I}$ and $\mathbf{G} - \mathbf{I}$ represent the demand-pull and cost-push effect, respectively.

2.5 Sectoral purchase coefficient

The sectoral purchase coefficient was adapted from Okuyama and Yu’s (2018) regional purchase coefficient. This stems from the following competitive I-O model:

$$\mathbf{x} = \mathbf{Ax} + \mathbf{f^d} + \mathbf{e} - \mathbf{m}, \tag{9}$$

where $\mathbf{x}$ is the total output vector, $\mathbf{A}$ is the technical coefficients matrix, $\mathbf{f^d}$ is the final domestic demand vector, $\mathbf{e}$ is the export vector and $\mathbf{m}$ is the import vector.

Equation 9 can be transformed into the following non-competitive I-O model:

$$\mathbf{x} = \mathbf{Ax} + \mathbf{f^d} + \mathbf{e} - \mathbf{M}\left(\mathbf{Ax} + \mathbf{f^d}\right) \tag{10}$$

through the import coefficient M_i expressed as:

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$$M_i = \frac{m_i}{\sum_{j=1}^{n} a_{ij}x_j + f_i^d}, \quad (11)$$

where m_i measures sector i's imports while M_i measures sector i's dependence on imports for its output production.

Alternatively, sector i's dependence on domestic inputs (or the domestic economy) to produce its output can be measured through the following sectoral purchase coefficient:

$$D_i = 1 - M_i. \quad (12)$$

2.6 Inoperability Input-Output model

One key extension of Leontief's I-O model was that of disaster modelling initially developed by Haimes and Jiang (2001) called the physical inoperability input-output model (IIM). This model was developed to measure each economic sector's inoperability – defined as the "inability of a system to perform its intended function" – as a result of a perturbation or external shock. Santos and Haimes (2004) further improved on this model by integrating the Leontief I-O model. This then led to the development of a demand-based IIM that defines inoperability as the normalized production loss caused by perturbations.[2] The model is expressed as:

$$\mathbf{q} = \mathbf{A}^*\mathbf{q} + \mathbf{c}^* \quad (13)$$

or:

$$\mathbf{q} = (\mathbf{I} - \mathbf{A}^*)^{-1}\mathbf{c}^*, \quad (14)$$

where $\mathbf{q}$ is the inoperability vector and each element q_i is defined as the ratio of the output loss (the difference between the ideal output level and the degraded output level) over the ideal output level. $\mathbf{A}^*$ is the interdependency matrix, where each element a_{ij}^* represents the inoperability sector i additionally contributes to sector j. $\mathbf{c^*}$ is the perturbation vector defined as the reduction of final demand, normalized according to the ideal output level. Each element c_i^* represents the demand-side perturbation. Lastly, the inoperability multiplier is defined as the column sums of $(\mathbf{I} - \mathbf{A}^*)^{-1}$. This measures the rate of increase in the level of inoperability caused by an additional perturbation.

3. Composite sector prioritization index

3.1 Normalization of the five sector significance measures

To ensure that the composite index generated by this study will meet the standards of a good index as defined by Eichhorn (1976), we adopt the following normalization process for each sector significance criteria, which will serve as the components of the index:

$$\ddot{e}_i = \frac{e_i}{\sum_{i=1}^{n} e_i}, \quad (20)$$

[2] Santos and Haimes (2004) provides a more extensive discussion of the IIM.

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where $\ddot{e}_i$ represents the element of the normalized criteria vector and e_i represents the element of a specific criterion's vector. Since all five sector significance measures have positive values, $\ddot{e}_i$ will range from 0 to 1. $\ddot{e}_i$ values approaching one will indicate that sector *i* must be prioritized in resource allocation decisions. Given this, we normalize the five criteria as follows:

Criterion 1: Power of dispersion index

Applying the normalization process to the power of dispersion index (Equation 3) generates the following:

$$\ddot{p}_i = \frac{p_i}{\sum_{i=1}^{n} p_i}, \tag{21}$$

where $\ddot{p}_i$ represents the relative influence of each sector on the rest of the economy, which also contributes to sector significance. A higher $\ddot{p}_i$ indicates that a final demand increase experienced by the respective sector generates a relatively greater impact on the output of other sectors in the economy. Hence, this implies that allocating more resources to these influential sectors will generate greater positive spillover effects on the rest of the economy.

Criterion 2: Sector size

Given that sector size is already normalized, we re-express Equation 4 as follows:

$$\ddot{x}_i = \frac{x_i}{\sum_{i=1}^{n} x_i}, \tag{22}$$

As mentioned earlier, a higher $\ddot{x}_i$ also indicates that sector *i* plays a larger role in the economy, specifically in terms of output production. Hence, this sector must be given priority with resource allocation.

Criterion 3: Average propagation length

Adopting the process of Yu et al. (2014), the average propagation length component, which measures a sector's number of inter-industry interactions, will be normalized as follows:

$$\ddot{s}_i = \frac{\sum_{j=1}^{n} s_{ji} + \sum_{j=1}^{n} s_{ij} - 2s_{ii}}{\sum_{i=1}^{n}\left(\sum_{j=1}^{n} s_{ji} + \sum_{j=1}^{n} s_{ij} - 2s_{ii}\right)}, \tag{23}$$

where $\sum_{j=1}^{n} s_{ji}$ represents the impact of a change in final demand of sector *i* or the backward APL, $\sum_{j=1}^{n} s_{ij}$ represents the impact of a change in the primary cost of sector *i* or the forward APL, and $2s_{ii}$ represents the initial impact of a change in either the primary cost or final demand of sector *i* on itself. This is eliminated in order to ensure that we are only measuring how many sectors sector *i* interacts with once, whether as a producer or a consumer.

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A higher $\ddot{s}_i$ indicates that the sector has a greater degree of interconnectedness as both a producer and consumer in the economy. This means that the sector is a key player in the economy and injecting more funds towards this sector will increase the reach or scope of the positive spillover effect on the economy.

Criterion 4: Sectoral purchase coefficient

Next, normalizing the sectoral purchase coefficient (Equation 12) generates the following:

$$\ddot{D}_i = \frac{D_i}{\sum_{i=1}^{n} D_i}, \tag{24}$$

where $\ddot{D}_i$ is the *i*th element of the normalized sectoral purchase coefficient matrix. Intuitively, a higher $\ddot{D}_i$ indicates that sector i is relatively more dependent on domestic inputs for its output production. Hence, exogenous shocks that hamper the production of domestic goods and services may severely impact sector i's output levels. This indicates that these sectors must be prioritized and given more resources to address the sector's vulnerability to the effects caused by shocks experienced by other sectors.

Criterion 5: Inoperability multiplier

We denote the inoperability multiplier generated from Equation 14 as m_i and apply the normalization process to generate the following:

$$\ddot{m}_i = \frac{m_i}{\sum_{i=1}^{n} m_i}, \tag{25}$$

where $\ddot{m}_i$ represents how much risk each sector contributes to the whole economy as a result of an exogenous shock. A higher $\ddot{m}_i$ indicates that the sector contributes to a larger degree of widespread inoperability as a result of perturbations, thus contributing to the sector's overall significance and prioritization level in the economy.

3.2 Composite index through Analytic Hierarchy Process

3.2.1 Composite index

Given that each sector significance criterion has been formally defined, we now define the composite index as:

$$R_i^* = W_{\ddot{p}}\ddot{p}_i + W_{\ddot{x}}\ddot{x}_i + W_{\ddot{s}}\ddot{s}_i + W_{\ddot{D}}\ddot{D}_i + W_{\ddot{m}}\ddot{m}_i, \tag{26}$$

where $0 \leq W_{\ddot{p}}, W_{\ddot{x}}, W_{\ddot{s}}, W_{\ddot{D}}, W_{\ddot{m}} \leq 1$

and $W_{\ddot{p}} + W_{\ddot{x}} + W_{\ddot{s}} + W_{\ddot{D}} + W_{\ddot{m}} = 1$.

Each weight $W_{\ddot{p}}, W_{\ddot{x}}, W_{\ddot{s}}, W_{\ddot{D}}, W_{\ddot{m}}$ will be generated using AHP explained below. R_i^* ranges between 0 and 1. A higher R_i^* indicates that the sector plays a key role in the overall economy.

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3.2.2 Analytic Hierarchy Process

The AHP was developed by Saaty (1980) as a type of multi-criteria decision analysis (MCDA) technique that involves gathering respondents' pairwise comparisons among different components to determine the relative importance of each criterion. The following steps, defined by Saaty (2008), were adopted in the study:

Step 1: Identifying the problem or goal of the study. As mentioned earlier, the goal of the study is to identify the key sectors in the economy based on five criteria of sector significance: power of dispersion index (degree of influence), sector size (structural significance), average propagation length (degree of interconnectedness), sectoral purchase coefficient (dependence on domestic economy), and inoperability multiplier (contribution to risk of inoperability). The key sectors will be identified from the following list of alternatives: Agriculture, Fishery and Forestry (AGR), Mining and Quarrying (MIN), Manufacturing (MAN), Construction (CONS), Electricity, Gas and Water (EGW), Transportation, Communication and Storage (TCS), Trade (TRD), Finance (FIN), Real Estate and Ownership of Dwellings (REAL), Private Services (PRIVSRV), and Government Services (GOVT). The study's AHP framework is summarized in Figure 1.

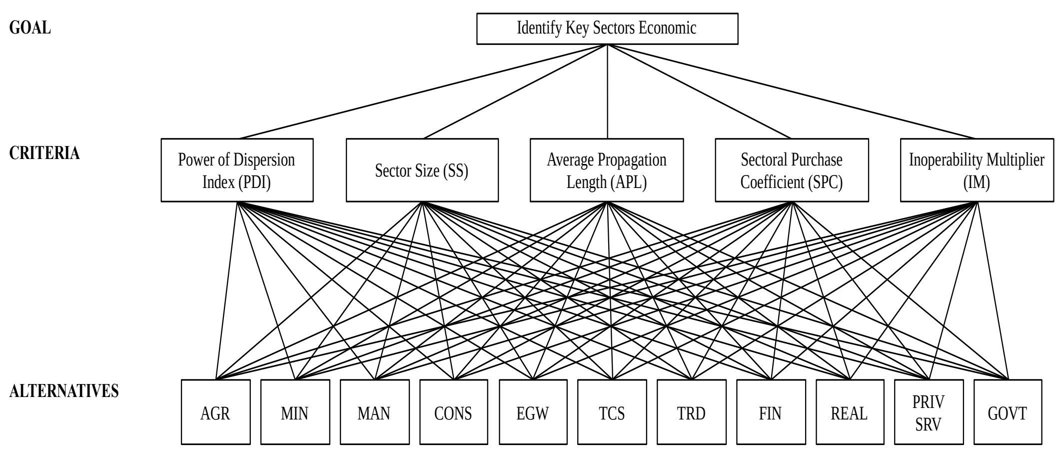

Figure 1 Sector prioritization index framework

Step 2: Construct the pairwise comparison matrix.

Given *n* number of criteria, the pairwise comparison matrix is defined as:

$$\boldsymbol{O} = [o_{ij}] = \begin{pmatrix} 1 & o_{12} & o_{13} & \cdots & o_{1n} \\ 1/o_{12} & 1 & o_{23} & \cdots & o_{2n} \\ 1/o_{13} & 1/o_{23} & 1 & \cdots & o_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 1/o_{1n} & 1/o_{2n} & 1/o_{3n} & \cdots & 1 \end{pmatrix}, \quad (27)$$

where o_{ij} is greater than zero and represents the average of the respondents' preference for criterion *i* over criterion *j* for $i, j = 1, \ldots, n$. It is important to note that $o_{ji} = 1/o_{ij}$. The respondents' pairwise comparison ratings range from 1 (equal preference for both measures) to 9 (extremely strong preference for one measure relative to another) as specified by Saaty (1980). Table 1 presents Saaty's scale of relative importance.

Table 1
Saaty's scale of relative importance

Rating	Preference
1	Equal Importance
3	Moderate Importance
5	Strong Importance
7	Very Strong Importance
9	Extreme Importance
2,4,6,8	Intermediate Values

Since this study makes use of five criteria for the composite index, the matrix from Equation 27 now becomes:

$$\boldsymbol{O} = [o_{ij}] = \begin{pmatrix} 1 & o_{12} & o_{13} & o_{14} & o_{15} \\ 1/o_{12} & 1 & o_{23} & o_{24} & o_{25} \\ 1/o_{13} & 1/o_{23} & 1 & o_{34} & o_{35} \\ 1/o_{14} & 1/o_{24} & 1/o_{34} & 1 & o_{45} \\ 1/o_{15} & 1/o_{25} & 1/o_{35} & 1/o_{45} & 1 \end{pmatrix}. \tag{28}$$

Step 3: Determine each criterion's level of priority or weight w_i.

The priority level w_i of criterion i is calculated through the following equation:

$$\boldsymbol{Ow} = \boldsymbol{\lambda_{max} w}, \tag{29}$$

where $\boldsymbol{w}$ is the vector of weights w_i and λ_{max} is the maximum eigenvalue.

Step 4: Evaluate the consistency of the pairwise comparisons.

To check whether the respondents provide a set of consistent preference ratings from the survey results, the consistency ratio (CR), defined by Equation 30 as the ratio between the consistency index (CI) of the pairwise comparison matrix and the consistency index of a randomly generated matrix (RI) was calculated. If CR is greater than 0.10, the respondents were asked to reconsider their initial preference rating to improve their judgments in case they inadvertently did not communicate their judgments well.

$$CR = \frac{CI}{RI}, \tag{30}$$

where CI is defined as:

$$CI = \frac{\lambda_{max} - n}{n-1} \tag{31}$$

and the RI values were generated by Saaty (2012) for various sizes of matrices as shown in the table below:

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Table 2
Consistency indices for random matrices

n	3	4	5
RI	0.58	0.9	1.12

4. Case study

This section features a case study to demonstrate the use of the composite sector prioritization index in the case of the Philippines, an archipelago comprised of 7,100 islands located along Southeast Asia. Its proximity to the Pacific Ring of Fire makes it susceptible to an array of natural hazards including typhoons, tsunamis, earthquakes, and drought. This makes the country prone to widespread output and economic loss. This geographic location allowed the Philippines to rank 5th in the global climate risk index and 3rd in the most high-risk developing countries in Asia in terms of disaster-driven economic loss (Eckstein, Künzel, & Schäfer, 2017; Asian Development Bank, 2013).

Because of this, the Philippines, as well as other disaster-prone countries, need efficient sector prioritization tools in order to manage sector vulnerability in times of crisis. Additionally, policymakers are also faced with the problem of scarce resources thus highlighting the need to efficiently allocate these to maximize gains and minimize losses in the economy. Hence, policymakers must identify and invest resources towards key sectors that are able to generate the largest positive spillover effects from the limited amount of resources given to them.

Since an economy has various priorities and concerns, policymakers must also be able to account for their respective economy's preferences when allocating resources. Given this, we adopted the AHP by selecting three key experts in the field of structural economics and the Philippine economy to properly mirror the country's preference assignments of the five sector significance criteria considered in the study.

Three Philippine economy experts, academicians, and policymakers[3] were selected to answer the AHP survey found in Appendix 1. Additionally, Table 3 specifies that the respondents' pairwise comparisons collectively generated a consistency ratio of 0.009[4]. Given this, the geometric means of the respondents pairwise comparisons were generated and used to determine the respective weights of the five sector significance criteria (see

[3] These experts include: (1) the Assistant Director of the National Economic Development Authority, (2) a professor from De La Salle University's School of Economics, and (3) a professor from the University of the Philippines's School of Economics.

[4] Each experts' pairwise comparisons were also found to be consistent as each expert yielded individual consistency ratios (CR) ranging from 0.0003 to 0.089, which are less than the 0.1 threshold. As expected, a consistency index of less than 0.1 has always been obtained from real experts who sincerely gave their judgments as pointed out by the reviewer in his/her over 24 years of experience implementing AHP/ANP on real decision making.

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Table 3)[5]. These weights were then multiplied to their corresponding sector significance criteria values. After which, the weighted values were added to obtain each sector's composite index value, which will be compared to identify the key sectors in the economy.

For this study, we used the 2012 Philippine Input-Output Table[6] published by the Philippine Statistics Authority to demonstrate the use of the index. Table 3 presents the summary of the pairwise comparison matrix and the AHP weights generated for 2012.

Table 3
Analytic Hierarchy Process weights

Indicator	PDI	SS	APL	SPC	IM	**Final Weight**
PDI	1.0000	1.5286	0.5228	1.9129	0.3293	0.1507
SS	0.6542	1.0000	0.3420	0.7114	0.2311	0.0880
APL	1.9128	2.9240	1.0000	2.0801	0.6300	0.2538
SPC	0.5228	1.4057	0.4807	1.0000	0.3029	0.1101
IM	3.0367	4.3271	1.5873	3.3014	1.0000	0.3973
Consistency Ratio						**0.0090**

As seen in Table 3, the economy gives a higher priority to sectors with higher inoperability multipliers or sectors, which largely contribute to the economy's risk of inoperability. This is possibly due to the Philippines' vulnerability to disaster-driven shocks making it prone to cyclical production disruptions and economic loss. Hence, this may cause policymakers to prefer to divert resources towards sectors which contribute to a greater amount of disaster-driven risk, in order to mitigate widespread inoperability and loss. Additionally, the country is also seen to prioritize sectors which have higher average propagation lengths or more interactions with the other sectors in the economy. This is understandable, especially since policymakers may opt to invest in sectors that can widen the scope of positive spillover effects through their large interconnections with the rest of the economy.

4.1 Sector prioritization results

Given the economy's preferences, Table 4 presents a comprehensive list of the composite sector prioritization indices and rankings per sector for the year 2012.[7]

As shown in Table 4, the key sectors of the Philippine economy are the manufacturing, private services, and trade sectors. This means that more financial aid and resources must be allocated towards the manufacturing sector as it has the ability to generate widespread inoperability and loss as a result of disruptions in the sector's operations. Since the

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[5] For ease, the AHP weights were calculated using Promentilla's AHP Calculator (2006) in Microsoft Excel 2016.
[6] The 2012 Philippine Input-Output Table is found in Appendix 2.
[7] The breakdown of the sector rankings with respect to each sector significance criteria is summarized in Appendix 3.

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manufacturing sector is a key consumer and producer of goods and services, disruptions experienced by this sector may cause production delays for sectors that rely on manufactured inputs and conversely, may also cause a decline in the manufacturing sector's demand for inputs from the rest of the economy. Overall, these may lead to demand- and supply-driven shocks that disrupt the operations of the rest of the economy. Additionally, since this sector is heavily interconnected with other economic sectors, investments or negative shocks experienced by the sector can easily be propagated to the rest of the economy. These, coupled with the sector's large output contribution or size, dependence on the domestic economy, and degree of relative influence, makes manufacturing a key sector to invest in as it can potentially generate higher positive spillover effects due to the magnitude and reach of its influence and interconnections. Conversely, these characteristics also make the sector highly vulnerable to large-scale loss and disruptions. Hence, these highlight the importance of prioritizing this sector in terms of resource allocation and disaster-risk management decisions.

Table 4
Composite index results (2012)

Sector	Composite Index	Rank
Agriculture, Fishery and Forestry	0.0825	6
Mining and Quarrying	0.0596	11
Manufacturing	0.1871	1
Construction	0.0820	7
Electricity, Gas and Water	0.0755	8
Transportation, Communication and Storage	0.0852	4
Trade	0.1070	3
Finance	0.0840	5
Real Estate and Ownership of Dwellings	0.0598	10
Private Services	0.1125	2
Government Services	0.0647	9

Moreover, the private services sector, which has been known to create services needed to support and sustain industrial sectors, like manufacturing, in their day-to-day operations was found to have the second highest ranking in the roster. This implies that much of the economy's financial aid must be allocated towards this sector to ensure that the country's industries remain afloat. Otherwise, disruptions experienced by this sector may lead to large-scale inoperability and loss because of its large contribution to risk and high degree of interindustry relations. Additionally, its output is highly dependent on the operations of industrial sectors, thus making it vulnerable to shocks experienced by the domestic economy. Hence, much of the economy's resources must be allocated towards this sector because of the risks it may contribute due to the disruptions that the Philippine economy may experience.

Furthermore, the trade sector also had a high priority ranking. More investment must then be directed towards this sector, as the Philippines heavily depends on its operations to fuel its economy. The country's dependence on this sector also implies that disruptions experienced in the industry may cause production delays and disruptions to proliferate towards the rest of the economy. Aside from the trade sector's structural significance and contribution to risk, its interdependence with other sectors in the economy makes it a crucial sector especially since many sectors depend on the sales or demand of their goods and services to fuel their production. Conversely, this also means that the trade sector relies on these other sectors' output to continue its operations. These make the trade sector an ideal industry to invest in as it is highly vulnerable to shocks and has the ability to potentially propagate small investments into larger positive spillover effects across the entire economy.

Additionally, we can observe that the following sectors received mid-priority rankings: (1) transportation, communication and storage, (2) finance, and (3) construction because all three sectors have less interindustry interactions and lower sector sizes relative to the other economic sectors. Hence, these sectors are less likely to contribute to large-scale disruptions, making them less crucial to invest in as these allocated large amounts of resources may only lead to minimal returns.

It is also interesting to note that the agriculture, fishery and forestry sector only received a mid-priority ranking despite its perceived vulnerability to calamities. This is possibly because the sector also has less interindustry interactions and influence on the rest of the economy, thus despite the sector's susceptibility to disruptions and output contribution, it is not deemed a priority due to its inability to generate large-scale spillover effects in the economy.

Aside from these, the electricity, gas and water, real estate and ownership of dwellings sectors, and mining and quarrying sectors received low-priority rankings among the other sectors in the roster because of their small contribution to the country's total output and risk of inoperability. These sectors are also known to have minimal interactions with other sectors in the economy due to the nature of their operations. Hence, this further contributes to their low dependence on the domestic economy and their low potential to propagate negative spillover effects towards the rest of the economy. Given this, policymakers must not prioritize these sectors when allocating financial aid and resources as they experience and contribute to less vulnerability risk.

Lastly, Table 3 also highlights the government sector's low-priority rankings. The structure of the Philippine economy illustrates that, while the government sector is usually given more priority in terms of resource allocation decisions, this may not necessarily be the case for all countries. Our findings affirm that the Philippine government sector has almost always taken on the role of a consumer rather than a producer of goods and services. This is because the Philippines is a developing and relatively young country, thus making its government less established and influential in propagating spillover effects towards other sectors in the economy due to its minimal interindustry interactions. Hence, allocating more financial aid towards this sector may only lead to minimal impacts on the economy.

5. Model limitation and future research

The current model assumes mutual independence among criteria in the computation of their importance weights that would influence the prioritization of the economic sectors.

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Our proposed framework, which was built from an AHP model, can thus be extended to the Analytic Network Process (ANP) model wherein the interdependence among criteria are made explicit and considered in sector prioritization (Saaty, 2006). Moreover, further research may explore the possibility of adding other sector significance criteria such as export contribution, employment contribution and import reliance to account for other possible concerns of the researcher's economy of choice. This study only makes use of five sector significance criteria to make the index more concise and specific to the primary needs of an economy. Other sector significance measures were also not included in the study due to lack of data but may be explored in future works. Nevertheless, the components used in this study can adequately provide insightful observations about each sector's role and relative importance in the economy. In addition, integrating alternative index aggregation techniques and weighting procedures is recommended to account for possible nonlinear relationships among the index components.

6. Conclusion

This paper developed a composite sector prioritization index that identifies the key sectors in the economy based on multiple dimensions of sector significance. This index is comprised of five key measures or criteria developed from I-O modelling to account for each sector's role and relative importance in the economy. First, the power of dispersion index measures a sector's relative influence or positive spillover effect in the economy. Second, the sector size measures a sector's output share or structural significance with respect to the entire economy. Third, the average propagation length measures a sector's number of interindustry interactions as both a consumer and producer in the economy. Fourth, the sectoral purchase coefficient measures a sector's dependence on the domestic economy for its output production, or vulnerability to domestic shocks. Lastly, the inoperability multiplier measures the sector's negative spillover effects or contribution to the economy's risk of inoperability. Additionally, this index was constructed using the Analytic Hierarchy Process, a systematic approach that allows us to reflect an economy's preference assignments for each sector significance criterion.

Because of these features, the composite index is considered a useful tool to aid policymakers in identifying which sectors to prioritize given the economy's varied priorities and preferences. This tool can benefit various stakeholders in their resource allocation decisions as it identifies the key economic sectors while accounting for a wider range of factors the economy may consider. Since this tool grants policymakers a broader view of an economy's various concerns, this allows them to determine which sectors are critically in need of investment and should be given the most priority in policy-related decisions. Through this, policymakers can effectively reduce the risk and production losses these critical sectors may propagate to the entire economy. Reducing widespread risk will then prevent other sectors from experiencing negative spillover effects thus promoting stable employment and economic prosperity, which in turn fosters sustainable and inclusive economic growth.

Using the case of the Philippines, we demonstrated the tool's ability to identify the key sectors to prioritize in order to efficiently manage widespread risk and maximize returns on investment. We were able to show that the policymakers give a higher priority to sectors that largely contribute to the economy's risk of inoperability. Given this, we found that the manufacturing, private services, and trade sectors received high priority rankings, indicating that these sectors' large contribution to the inoperability risk and significant industry interactions makes it highly vulnerable to and influential in propagating risk. Hence, more financial aid and resources must be allocated towards these sectors to prevent the widespread propagation of inoperability and to generate the highest possible impact on the rest of the economy. Prioritizing these sectors may also significantly improve the country's resilience and preparedness measures in the event of disruptions experienced by the economy. Overall, the case study was able to demonstrate the advantages of using this tool as it considers the priorities of the economy when identifying the key economic sectors to invest in. While this study highlights the application of the tool in the case of the Philippines, this sector prioritization index can easily be applied to various economies, which may grant us more insight into the possible similarities and differences among the key sectors of different nations.

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APPENDIX

Appendix 1

Analytic Hierarchy Process Questionnaire

In 2012, which of the attributes contributes more to the significance of a sector to the entire economy and by how much?

Power of Dispersion Index vs. **Sector Size**

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
Extremely higher		Very significantly higher		Significantly higher		Moderately higher		Equal Contribution		Moderately higher		Significantly higher		Very significantly higher		Extremely higher

Power of Dispersion Index vs. **Average Propagation Length**

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
Extremely higher		Very significantly higher		Significantly higher		Moderately higher		Equal Contribution		Moderately higher		Significantly higher		Very significantly higher		Extremely higher

Power of Dispersion Index vs. **Sectoral Purchase Coefficient**

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
Extremely higher		Very significantly higher		Significantly higher		Moderately higher		Equal Contribution		Moderately higher		Significantly higher		Very significantly higher		Extremely higher

Power of Dispersion Index vs. **Inoperability Multiplier**

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
Extremely higher		Very significantly higher		Significantly higher		Moderately higher		Equal Contribution		Moderately higher		Significantly higher		Very significantly higher		Extremely higher

Sector Size vs. **Average Propagation Length**

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
Extremely higher		Very significantly higher		Significantly higher		Moderately higher		Equal Contribution		Moderately higher		Significantly higher		Very significantly higher		Extremely higher

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Sector Size								vs.	Sectoral Purchase Coefficient							
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
Extremely higher		Very significantly higher		Significantly higher		Moderately higher		Equal Contribution		Moderately higher		Significantly higher		Very significantly higher		Extremely higher

Sector Size								vs.	Inoperability Multiplier							
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
Extremely higher		Very significantly higher		Significantly higher		Moderately higher		Equal Contribution		Moderately higher		Significantly higher		Very significantly higher		Extremely higher

Average Propagation Length								vs.	Sectoral Purchase Coefficient							
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
Extremely higher		Very significantly higher		Significantly higher		Moderately higher		Equal Contribution		Moderately higher		Significantly higher		Very significantly higher		Extremely higher

Average Propagation Length								vs.	Inoperability Multiplier							
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
Extremely higher		Very significantly higher		Significantly higher		Moderately higher		Equal Contribution		Moderately higher		Significantly higher		Very significantly higher		Extremely higher

Sectoral Purchase Coefficient								vs.	Inoperability Multiplier							
9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
Extremely higher		Very significantly higher		Significantly higher		Moderately higher		Equal Contribution		Moderately higher		Significantly higher		Very significantly higher		Extremely higher

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Appendix 2
2012 Philippine Input-Output Table (in Millions of Philippine Pesos)

	AGR	MIN	MAN	CONS	EGW	TCS	TRD	FIN	REAL	PRIVSRV	GOVT	f	X
Agriculture, Fishery and Forestry	264,256,364.48	1,314,816.73	750,262,030.24	33,212,393.32	3,785,050.61	9,042,326.73	50,023,052.70	6,217,225.93	11,686,543.00	104,440,578.55	2,748,526.65	908,331,258.51	2,145,320,167.46
Mining and Quarrying	73,872.21	301,459.72	310,676,086.17	49,078,614.72	14,235,501.06	188,947.91	4,253,668.66	44,581.53	1,420,463.38	1,317,117.82	16,748.83	-198,431,894.53	183,175,167.46
Manufacturing	130,410,148.74	8,334,407.42	1,803,375,804.27	317,366,034.08	81,126,761.82	242,411,790.82	438,051,559.22	40,455,469.23	31,138,668.88	449,751,132.48	15,753,399.88	2,809,121,723.25	6,367,296,900.09
Construction	238,415.80	4,672,076.66	54,447,332.78	2,609,838.03	8,542,123.38	19,021,239.56	26,526,666.61	5,729,345.82	9,506,262.57	32,880,346.96	195,278.41	861,736,567.13	1,026,105,493.70
Electricity, Gas and Water	4,362,862.51	1,459,164.97	110,616,825.02	5,265,797.90	85,371,755.51	36,342,768.04	98,902,785.75	7,556,734.22	8,277,136.80	123,197,064.59	3,122,662.59	336,584,575.01	821,060,132.90
Transportation, Communication and Storage	15,542,905.71	1,363,400.97	175,545,943.70	7,048,505.10	1,786,259.39	113,246,607.89	118,357,972.74	25,826,586.64	5,323,419.63	88,117,979.11	34,688,454.55	867,908,894.99	1,454,756,930.42
Trade	158,873,898.28	15,571,097.27	683,355,097.67	113,548,388.74	50,834,142.30	158,027,834.31	468,050,239.55	121,692,807.02	78,903,283.01	452,855,350.73	26,845,941.28	837,001,853.81	3,165,559,933.97
Finance	15,839,566.37	1,051,685.48	103,000,998.58	22,689,415.77	9,620,010.58	85,378,476.31	196,718,491.77	306,646,251.49	14,994,724.22	156,084,712.07	29,852,682.08	512,084,509.29	1,453,961,524.00
Real Estate and Ownership of Dwellings	27,117.15	1,679,124.91	17,946,614.77	883,939.15	1,596,924.54	6,355,796.37	8,084,416.59	2,103,912.51	3,348,457.65	10,221,245.06	43,945.37	674,754,278.24	727,045,772.31
Private Services	62,200,488.74	6,791,469.35	246,965,842.61	47,775,511.13	7,886,466.04	72,322,147.13	101,400,021.43	81,428,321.28	23,960,268.39	435,791,494.77	68,407,674.80	2,497,170,641.45	3,652,100,347.11
Government Services	429.83	62,092.09	3,079,103.35	306,784.60	69,369.49	3,603,818.22	21,994,203.52	5,001,537.31	1,225,414.95	17,415,068.85	60,330,065.13	568,550,196.44	681,638,083.77

Appendix 3
Breakdown of Rankings for Each Sector Significance Criteria

SECTOR	PDI	PDI Rank	SS	SS Rank	APL	APL Rank	SPC	SPC Rank	IM	IM Rank
Agriculture, Fishery and Forestry	0.0774	9	0.0990	4	0.1000	4	0.0983	7	0.0653	7
Mining and Quarrying	0.0725	11	0.0084	11	0.1070	1	0.0300	11	0.0440	11
Manufacturing	0.1157	1	0.2937	1	0.1023	3	0.0695	10	0.2773	1
Construction	0.1097	2	0.0473	7	0.0767	9	0.1044	3	0.0763	4
Electricity, Gas and Water	0.0800	8	0.0379	8	0.1000	4	0.1046	1	0.0585	8
Transportation, Communication and Storage	0.1015	3	0.0671	5	0.0930	8	0.0944	8	0.0754	5
Trade	0.0975	5	0.1460	3	0.0977	6	0.0997	6	0.1100	3
Finance	0.0881	6	0.0671	6	0.1047	2	0.1013	5	0.0682	6
Real Estate and Ownership of Dwellings	0.0747	10	0.0335	9	0.0558	11	0.1045	2	0.0503	10
Private Services	0.1001	4	0.1685	2	0.0977	6	0.0900	9	0.1205	2
Government Services	0.0827	7	0.0314	10	0.0651	10	0.1033	4	0.0543	9

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