Thermoeconomical Productivity Analysis in Manufacturing Sector in Indonesia

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Abstract. Negative temperature is a phenomenon interesting to study. In negative temperature regime, Boltzmann distribution is inverted where many particles occupy the higher energy states than the lower one. Iyetomi proposed a negative temperature case in Japan and applied it to the labor productivity distribution where the particle and energy state are replaced by worker and labor productivity, respectively. In this paper, we investigate the negative temperature concept to the labor productivity distribution in manufacturing sector in Indonesia which is divided by three industry groups according to BPS (Center of Statistical Agency of Indonesia), i.e. large and medium industries, small industry, and micro industry. For all industry groups, food industry possesses maximum productivity. The results represent that the negative temperature of large and medium industries is around ten times lower than negative temperature of micro industry indicating large and medium industries is lack demand of worker, while the negative temperature of small industry is among the temperature negative of large and medium industries and micro industry.

1. Introduction
Manufacturing industry in Indonesia is one of the economic sectors that undergoes fast economic growth. This sector has the largest contribution to Indonesia’s Gross Domestic Product \cite{3} i.e. important indicator of economic condition in Indonesia. Moreover, manufacturing industry also absorbs many workers. Hence, productivity of worker in the industry possesses important contribution to the national economy.

Iyetomi initiated that labor productivity distribution in Japan which consists of manufacturing sector and nonmanufacturing sector could be approximated with negative temperature distribution \cite{1}. At negative temperature, particles possess unusual distribution over energy states. He adopted negative temperature concept in order to give new insight of the macroeconomy. In this circumstance, zero temperature in negative temperature regime indicated the highest productivity of worker.

In this study, negative temperature in the distribution of workers over their productivity was investigated in manufacturing sector in Indonesia. Empirical results of the distribution led us to know the possibility of negative temperature in its sector as proposed by Iyetomi. The negative temperature provided an overview to the amount of demand of workers to increase the productivity in certain industry.
2. Negative Temperature
The probability of finding particles at certain energy state is related to the Boltzmann distribution which describes that the probability varies exponentially as a function of $E_i/k_BT$. The relationship between probability of particles to occupy energy states and its energy states is given by

$$P_i \propto \exp\left(-\frac{E_i}{kT}\right),$$

where $P_i$ denotes the probability at the $i$-th energy state $E_i$ at a temperature $T$ and $k_B$ denotes the Boltzmann’s constant.

In common physical system, $P_i$ decreases exponentially as $E_i$ increases at positive temperature. On the other hand, the number of particles decrease as the energy in system raises. Under certain condition, probability over all energy states are identical which is indicated by similar number of particles for all energy states. This condition occurs at infinity temperature.

In contrast, If we substitute $T < 0$ K on (1), $P_i$ increases exponentially as $E_i$ raises. At negative temperature, most of particles occupy the higher energy states than the lower energy states led to decreasing entropy. Therefore, the number of particles increase exponentially as the energy raises.

At negative temperature, $P_i$ is divergent as $E_i$ approaches infinity [2]. Therefore, negative temperature requires upper limit energy indicated by -0 K. At that circumstance, all particles are at the highest energy state as the energy in system is maximum. The entropy becomes zero indicating all particles occupy the highest energy state. The probability would be maximum at that energy state.

3. Labor Productivity Distribution in Japan
Negative temperature concept could be applied to the labor productivity distribution as Iyetomi proposed. Based on his work, empirical results of the labor productivity distribution in Japan consist of manufacturing sector and nonmanufacturing sector (Figure 1) where those sectors consist of around 480,000 firms (Figure 1).

According to Iyetomi’s research, the distribution of both sectors has sharp cups around $c = c^*$. In this circumstance, $c^*$ indicates maximum productivity of workers. The number of workers $n(c)$ of both distributions tend to monotonic increase at $c < c^*$. In contrast, at the region $c > c^*$, $n(c)$ decrease of both sectors.
Iyetomi initiated Boltzmann distribution of workers over productivity:

\[ n(c) = N\lambda \exp\left( -\frac{c}{T} \right), \]  \hspace{1cm} (2)

where \( T \) is economic temperature indicating how large the demand of workers diminishes away from its maximum. The maximum condition is accomplished where all workers have maximum productivity. \( N\lambda \) on (2) is related to equilibrium condition of two subsystems.

The equilibrium condition based on iyetomi’s work consists of two condition

\[ T_A = T_B, \]  \hspace{1cm} (3)

and

\[ N_A\lambda_A = N_B\lambda_B. \]  \hspace{1cm} (4)

The first condition (3) describes the equilibrium of demand of workers, while the second condition (4) reveals the equilibrium of the number of workers between two subsystems. If \( T_A > T_B \) then the demand of workers flow from subsystem A to subsystem B. \( N_A\lambda_A > N_B\lambda_B \) indicated the workers flow from A to B and vice versa.

Recall from Iyetomi, the average number of workers increase as the productivity is raised. In this circumstance, workers are regarded as particles and their productivity are considered as energy states of particles. Therefore, he allows us to adopt the concept of negative temperature formed with maximum productivity \( c^* \).

Figure 2. Fitting of labor productivity distribution in term Boltzmann distribution. Both axes are in logarithmic scales [1].

Least square fitting exponential to the Boltzmann form (Figure 2) of both distributions represents the exponential growth of the distribution of workers over productivity. Hence, economic temperature is negative. \( T \) and \( N\lambda \) parameter could be determined by least square method based on Iyetomi’s work.
4. Labor Productivity Distribution in Manufacturing Sector in Indonesia

4.1. Productivity data
We collected data of the productivity \( c \) and data of the number of workers \( n(c) \) compiled by BPS i.e. Center of Statistical Agency in Indonesia (www.bps.go.id). According to BPS, manufacturing sectors in Indonesia are divided by three groups:

- Large and medium industries (>19 people)
- Small industry (1-19 people)
- Micro industry (1-4 people)

In this study, we classified \( c \) and \( n(c) \) of large and medium industries in 2008-2013, while \( c \) and \( n(c) \) of micro and small industries are in 2010-2015.

Large and medium industries consist of 24 subsectors based on KBLI i.e. Indonesia’s standard industrial classification in 2009, there are:

- Food
- Drink
- Tobacco
- Textil
- Clothes
- Leather
- Wood
- Paper
- Printing
- Coal and crude oil
- Chemical
- Pharmacy
- Rubber
- Nonmetallic mineral product
- Base metal
- Metal product
- Computer
- Electric product
- Mechanic
- Motor Vehicle
- Other transportation
- Furniture
- Other manufacturing
- Reparation services

Micro and small industries consist of 23 subsectors in which coal and crude oil industrial subsector were not included.

Labor productivity is defined as total output divided by the number of paid labor [4]. We could write the productivity of subsector \( i \) as \( c_i \):

\[
c_i = \frac{O_i}{n_i},
\]

where \( O_i \) and \( n_i \) represent the total output and the number of workers of subsector \( i \). We should calculate \( c_i \) of micro and small industries by using (5). In contrast, we did not need to calculate \( c_i \) of large and medium industries since their productivity data were already provided in BPS.
4.2. Empirical results

We plotted \( n(c) \) respect to \( c \) for each industry groups to obtain the distribution of workers over their productivity. Each distribution has the maximum peak indicating maximum productivity of workers \( c^* \) (Figure 3). \( c^* \) of large and medium industries, small industry, and micro industry are around 270 million rupiah, 96 million rupiah, and 31 million rupiah, respectively. Food industry has the maximum productivity over all distributions in 2013.

![Figure 3. Empirical results of the distribution of workers over productivity for each industry groups in 2013.](image)

We did not use logarithmic scale to plot \( n(c) \) since we lack of data from BPS. Moreover, we avoid to apply logarithmic scale on the distributions in order to indicate the difference of distribution as they are in \( c < c^* \) and also in \( c > c^* \). The distributions at \( c < c^* \) have shorter interval than those at \( c > c^* \). The average number of workers at \( c < c^* \) is greater than those at \( c > c^* \). For all distribution, the number of workers decrease drastically at \( c > c^* \).

4.3 Exponential fitting of the labor productivity distribution

According to the distributions as shown in Figure 3, we could not fit the distributions with least square method. The distributions above are fluctuate. However, at each distribution, there is one highest peak indicating maximum productivity. In case of negative temperature, the maximum productivity indicated the upper limit of energy. In this circumstance, perhaps it allowed us to apply inverted Boltzmann distribution. On the other hand, exponential growth fitting could be applied to the distributions.

In this study, we formed exponential growth curve to the distributions as:

\[
n(c) = a \exp(bc),
\]

where

\[
a = N\lambda,
\]

and

\[
b = -\frac{1}{T}.
\]
\(a\) and \(b\) are guessed such that they could appropriate with the distributions. Therefore, we obtained \(N\lambda\)

and \(T\) parameters of each distributions.

**Figure 4.** Exponential fitting curves appropriated to the distributions of each industry groups in 2013.

Exponential growth curve of each distribution indicated how many number of workers required to increase productivity in certain industry group (Figure 4). Exponential curve increasing rapidly indicates the great amount of the demand of workers. Exponential growth curve of large and medium industries are slower to increase than it of micro and small industries. Micro industry has the highest increment of exponential curves, while exponential curve of small industry is among micro industry and the large and medium industries.

### 4.4 \(T\) and \(N\lambda\) parameters

The results of \(T\) and \(N\lambda\) for each industry group are shown in Figure 5, 6, and 7 as initiated by Iyetomi where the blue color denotes \(T\) and the green color denotes \(N\lambda\).

**Figure 5.** \(T\) and \(N\lambda\) parameters of large and medium industries in the period 2008-2013.
Figure 6. $T$ and $\lambda$ parameters of small industry in the period 2010-2015.

Figure 7. $T$ and $\lambda$ parameters of micro industry in the period 2010-2015.

$T$ of large and medium industries are lower around ten times than it of micro industry indicating the demand of workers in micro industry is greater than it in large and medium industries. These results are quite perceptible. Micro industry requires more amount of workers than large and medium industries in order to increase their productivity since the resources are more limited in micro industry than those in large and medium industries. The large and medium industries will optimize their resources before they increase the demand of workers to increase their productivity. $T$ of small industry is among $T$ of micro industry and $T$ of large and medium industries. Economic temperature of micro and small industries tends to increase in the period 2010-2011. In contrast, their economic temperature tend to decrease in period 2011-2015. In 2011, both economic temperatures are the highest indicating the highest demand of workers of both industries.

In this study, we could not determined the results of $T$ exactly, moreover in respect of $\lambda$. In Figure 5, 6, and 7 we obtained $\lambda$ tends to equilibrium. In the right of fitting procedure by using the large amount of productivity data, however, the result of $\lambda$ might be different.

5. Conclusion
We knew that the data of labor productivity in Japan is around 480.000 data, while data in this study are only 24 data for large and medium industries and 23 data for small and medium industries. We worked with 24(23) data to represent labor productivity distribution in Indonesia, particularly in
manufacturing sector. The distributions of each industry groups had one highest peak indicating maximum productivity of workers. Therefore, there might be a negative temperature where the Boltzmann distribution is inverted. For each industry group, the results of $T$ are quite understandable and they could describe the demand of workers adequately. In contrast to the results of $N\lambda$ which they could not be determined by our fitting procedure.

In the future research, we require to use more productivity data with the productivity data of firm for each industry groups in manufacturing sector as initiated by Iyetomi. Hence, the distribution of $n(c)$ over $c$ will not fluctuate in order to use well the fitting procedure.

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