Dynamics of Economic and Environmental Returns of Implementing a Circular Economy Concept

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***Abstract* - A circular economy concept has been implemented in many countries to unbundle the environmental pressure from an economic growth. However, most research focuses on the environmental impact and resource scarcity dimensions of circular economy. Economic benefits were missing from the discussion. This paper used system dynamics approach to observe the pattern of economic returns from implementing a circular economy. The findings are the circular economy approach increase, instead of decrease, firms' pollution emission. Firms' will have lower retained earnings in a short run but it will be offset with higher retained earnings in a long run.**

***Keywords* - Circular economy, economic returns, system dynamics**

I. INTRODUCTION

An economic growth has been a core direction for almost every country. However, there are issues on resource scarcity and environmental impacts of an economic growth, such as a case of China. A circular economy concept was emerged as a concept to unbundle the economic growth from the limitation of resource scarcity and environmental impact through 3R (Reduce, Reuse, Recycle) approach [1].

Even though the circular economy concept is good for the country's growth, it has implementation difficulties. Most of the discussion on a circular economy was focused on the role of a circular economy on overcoming a resource constraint problem and how to reduce the impact of an economic growth on environmental quality. However, the discussion on economic benefits of circular economy has not been put on a table [2, 3]. This is an important problem because the key implementers of a circular economy are companies and their primary concern is the bottom line. Therefore, this paper's key contribution is to analyze the pattern of economic benefits of implementing a circular economy at the firm level.

The results show that a circular economy can improve firms' economic benefits indicating from a higher profit. Firms implementing a circular economy will have lower retained earnings in a short run but they will gain much more retained earnings in a long run. For environmental benefits, the better resource usage efficiency increases the output of the firms, which turns out to create more pollution in total.

II.LITERATURE REVIEW

The concept of a circular economy comes from a perspective shift of the resource constraint. Before an introduction of a circular economy, the resources were viewed as unlimited and sufficient to support the growth of the countries. In 1966, there was another thought that a world can be viewed as a spaceship going for a long journey with limited resources [4]. This approach was strongly supported by China. China faced a problem of resource scarcity and environmental challenges from a rapid industrialization [5]. To tackle this problem, China introduced the Circular Economy Promotion Law to improve resource utilization efficiency, protect natural environment, and enhance sustainable development [3].

The implementation of circular economy in China is unique because it uses a top-down approach which the direction was enforced by the government. However, the development of a circular economy in other countries is relatively young. Some researchers suggested that the missing link is the economic benefits of a circular economy are not widely discussed. The circular economy was focused on how a circular economy can support an economic growth under a resource scarcity and how a circular economy can reduce an impact of an economic growth on the environmental quality. However, the key implementers of a circular economy are companies which focuses on the economic benefits of implementing a circular economy [2, 3, 5]. This claim was supported by the assessment system of China's circular economy performance which focuses only on four dimensions – resource output, resource consumption, integrated resource utilization, and waste disposal and pollutant emission – and only on regional and industrial park level. [3]

III. METHODOLOGY

It is challenging to analyze the economic benefits of implementing a circular economy approach using an empirical method because the performance of the firms implementing a circular economy approach depends on many factors which relate to one another. In addition, due to a data limitation, there is no baseline of what the firms would be if they didn't apply a circular economy approach. To overcome this difficulty, we use a system dynamics approach. The system dynamics approach is a mathematical simulation approach. The model has been used in a complex system that consists of multiple factors interact with each other at the same time [6]. This method has a unique capability in analyzing the policy prior to actual implementation [7]. It has been used in multiple situations such as an industrial growth [8, 9] and country's growth [10, 11].

The model is based on the extant theory and literature on circular economy. The model can overcome the aforementioned research limitation through a simulation of the performance when the firm did not implement a circular economy approach comparing with the case that the firm implements a circular economy approach.

IV. MODEL

The model is developed from the work of George, et al. [12], which categorized input into a recyclable input and a polluting input. The implementation of a circular economy approach is added into the model through an increase in recyclable input usage. The economic benefits of using a circular economy approach will be determined through the profit and retained earnings of the firm. In addition to the economic benefits of implementing a circular economy, we also observe the environmental impact. However, the role of a circular economy in solving a resource constraint problem is not addressed here.

The firm's profit comes from a revenue, which is depended on the output of the firm. High production output requires more input, which is categorized into recyclable input and polluting input. The amount of both inputs is depended on the production plan, which is estimated from a target profit that is depended on the profit in the previous year. The explained relationships are illustrated in Fig.1.

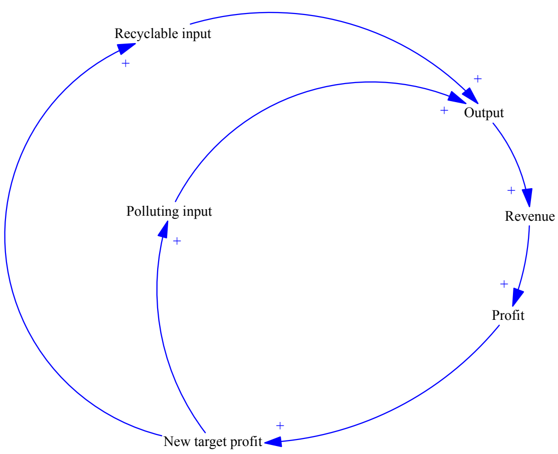

Fig. 1 Model showing relationships among revenue, profit, input, and output

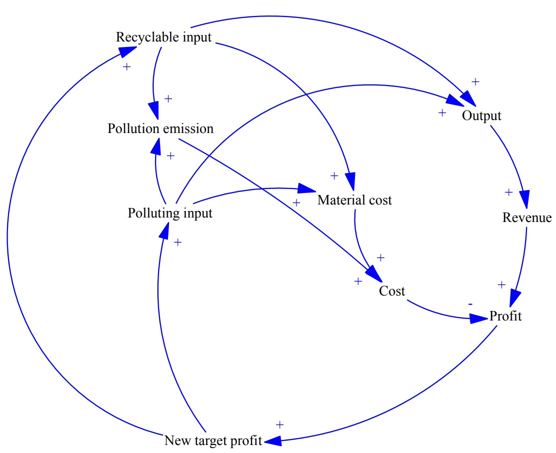

Fig. 2 Model showing relationships between inputs, pollution emission, cost, and profit

High volume of recyclable inputs and polluting inputs does not only increase the output of the firm, but it also increases the material costs. In addition, when firms use more inputs for their operation, there will be more pollution that is emitted to the environment. This pollution becomes an environmental cost for the firms because firms need to invest in pollution-cleaning infrastructure or to pay for social cost to compensate for their pollution. These costs will reduce the firms' profit as shown in Fig.2.

Firms' profit is accumulated into retained earnings and it will be used to invest in firms' strategic project. In this case, this strategic project is the circular economy project. By investing in a circular economy project, firms will use more recyclable input and less polluting input per unit of output, as shown in Fig.3.

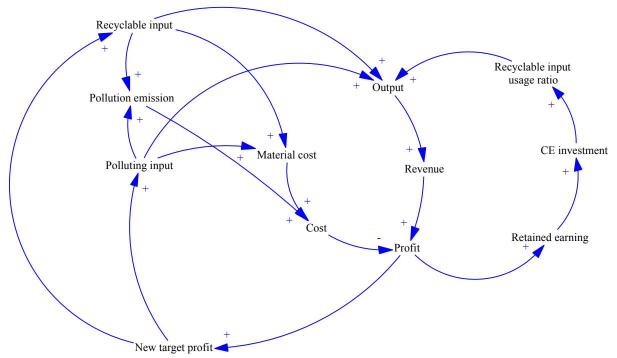

Fig. 3 Model showing an investment in a circular economy project

The model shown here is the conceptual model showing the relationships among factors that are related to this problem. The actual mathematical model is attached in the appendix.

V. RESULTS

The model was simulated to observe between the situation that the firms do not implement a circular economy and firms implement a circular economy. If the firms do not implement a circular economy approach, firms' profit is increased sharply and then an increase will become gradual as illustrated in Fig.4. Due to a continuous increase in profit, firms' retained earnings keep growing over time as shown in Fig. 5. The emitted pollution is in the same pattern as the profit that the pollution emission jumps up significantly during the first period and then stable as shown in Fig. 6.

In the model, firms implement a circular economy approach by reducing the target ratio of using polluting input from 100% to 90% at time 0. The results show that when the circular economy is implemented, firms' retained earnings drop significantly due to an circular economy project investment. However, after a period of time, the retained earnings increase and become higher than that when a circular economy is not implemented. The result is illustrated in Fig. 7.

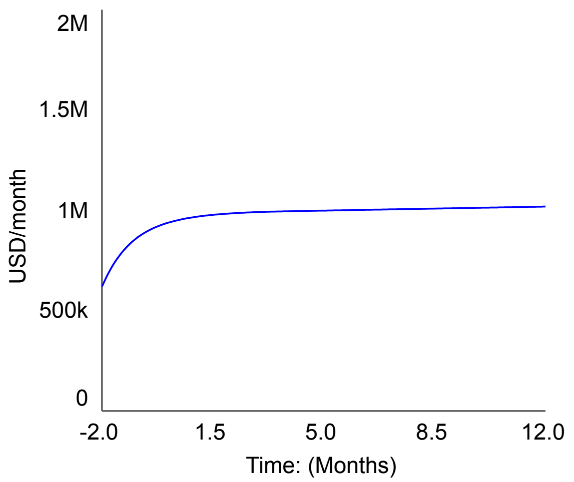

Fig. 4 Firm's profit if firms do not implement a circular economy approach

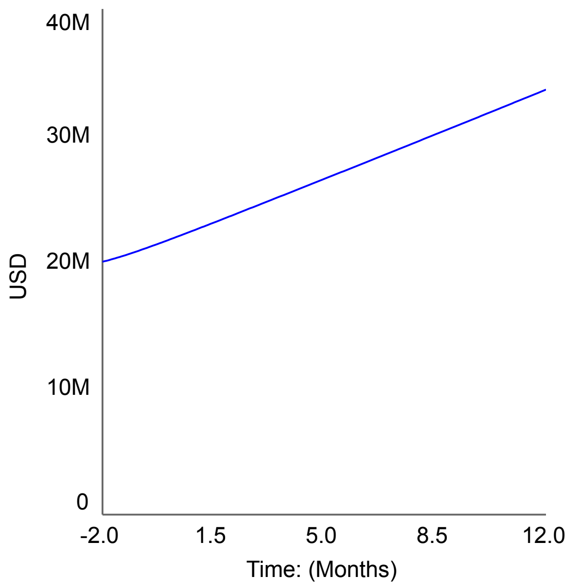

Fig. 5 Firms' retained earnings if firms do not implement a circular economy approach

Considering the firms' profit, Fig. 8. shows that the profit of the firm increases exponentially after the circular economy is implemented. However, firms also produce more pollution after the circular economy is implemented too, as shown in Fig. 9.

This result is interesting that the circular economy does not reduce the pollution emission but, on the other hand, firms produce more pollution after they implement a circular economy approach. This finding supports the "rebound" effect literacy that an improvement in productivity of resources causes an increase in production volume, which in turn creates more pollution in total, as shown in Fig. 10 [1].

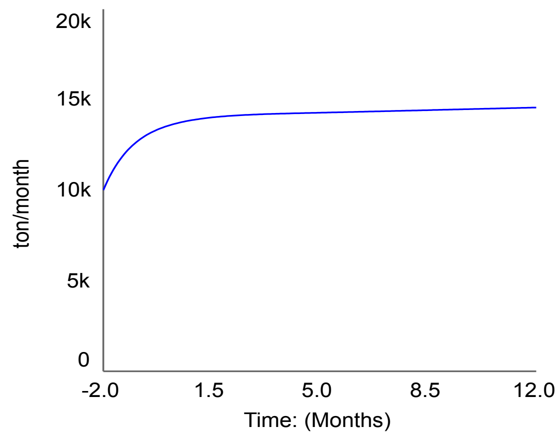

Fig. 6 Firms' pollution emission if firms do not implement a circular economy approach

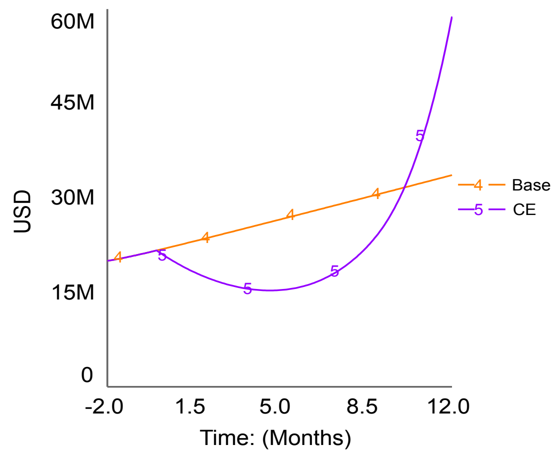

Fig. 7 Comparing firms' retained earnings when a circular economy approach is and is not implemented

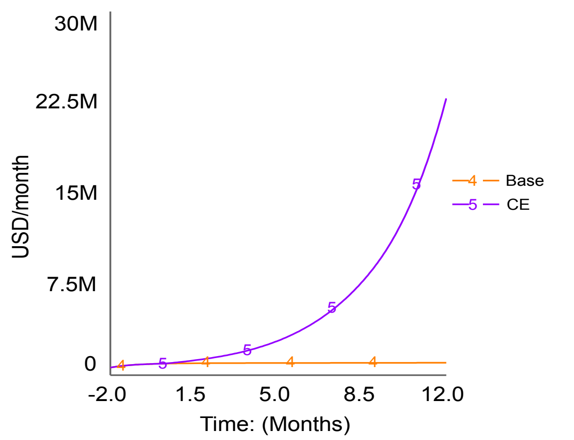

Fig. 8 Comparing firms' profit when a circular economy approach is and is not implemented

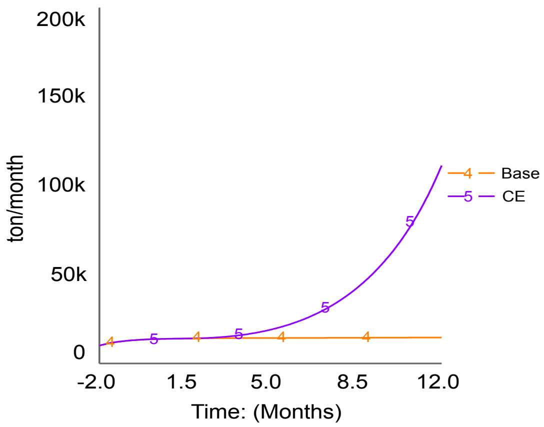

Fig. 9 Comparing firms' pollution emission when a circular economy approach is and is not implemented

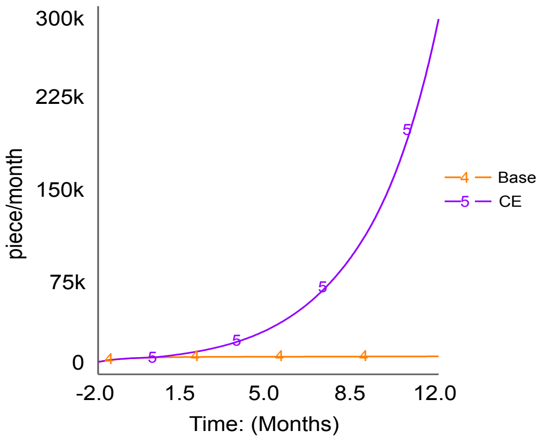

Fig. 10 Comparing firms' output when a circular economy approach is and is not implemented

VI. CONCLUSION AND IMPLICATION

This paper analyzes the economic and environmental returns of implementing a circular economy approach by using a simulation model developed from the concept portrayed in George, et al. [12]'s paper. The results show that by implementing a circular economy, firms will gain significant economic benefits in term of production output and profit. However, firms' retained earnings will reduce first and rebound strongly later. However, after implementing a circular economy approach, firms produce more, instead of less, pollution due to a jump in firms' output. These results indicate that implementing a circular economy alone cannot improve the environmental quality in a long run and firms can gain significant economic benefits from implementing a circular economy approach.

These results lead to an implication for practitioners that firms' executive should consider implementing a circular economy approach because it will create a long-term benefit for the firms, even though a short-term investment cost is large. However, if firms also concern about the environment, firms should also consider other approaches to complement a benefit from a circular economy.

This research also creates a theoretical contribution that the rebound effect is important and should be seriously considered. An increase in output from more efficient resource usage can turn the environmental-friendly project into a disaster for environment. A production limitation should also be considered in accompany with the circular economy approach.

VII. APPENDIX: THE MATHEMATICAL MODEL

Top-Level Model:
"On-process_new_polluting_input"(t) = "On-process_new_polluting_input"(t - dt) + (New_polluting_input_order - Polluting_input_obtain) * dt
INIT "On-process_new_polluting_input" = "Initial_on-process_new_polluting_input"
INFLOWS:
New_polluting_input_order = New_polluting_input/Input_order_duration
OUTFLOWS:
Polluting_input_obtain = "On-process_new_polluting_input"/Time_to_obtain_input
"On-process_new_recyclable_input"(t) = "On-process_new_recyclable_input"(t - dt) + (New_ordered_recyclable_input - New_recyclable_input_delivered) * dt
INIT "On-process_new_recyclable_input" = 0
INFLOWS:
New_ordered_recyclable_input = New_recyclable_input/Input_order_duration
OUTFLOWS:
New_recyclable_input_delivered = "On-process_new_recyclable_input"/Time_to_obtain_input
Polluting_input_ratio(t) = Polluting_input_ratio(t - dt) + (- Input_ratio_reduction) * dt
INIT Polluting_input_ratio = Initial_polluting_input_ratio
OUTFLOWS:
Input_ratio_reduction = Invest_for_CE/Input_reduction_to_investment_ratio
Polluting_input_stock(t) = Polluting_input_stock(t - dt) + (Polluting_input_obtain - Polluting_input_usage) * dt
INIT Polluting_input_stock = Initial_polluting_input_stock
INFLOWS:
Polluting_input_obtain = "On-process_new_polluting_input"/Time_to_obtain_input
OUTFLOWS:
Polluting_input_usage = Polluting_input_stock/Time_to_destock_input
Recyclable_input_stock(t) = Recyclable_input_stock(t - dt) + (New_recyclable_input_delivered + Recycled_input_usage - Recyclable_input_usage) * dt
INIT Recyclable_input_stock = 0
INFLOWS:
New_recyclable_input_delivered = "On-process_new_recyclable_input"/Time_to_obtain_input
Recycled_input_usage = Recycled_input/Recycled_input_usage_duration
OUTFLOWS:
Recyclable_input_usage = Recyclable_input_stock/Time_to_destock_input

Recycled_input(t) = Recycled_input(t - dt) + (New_recycled_input - Recycled_input_usage) * dt
INIT Recycled_input = 0
INFLOWS:
New_recycled_input = Recyclable_input_usage*Recycle_ratio
OUTFLOWS:
Recycled_input_usage = Recycled_input/Recycled_input_usage_duration
Retained_earning(t) = Retained_earning(t - dt) + (Profit - Invest_for_CE) * dt
INIT Retained_earning = Initial_retained_earning
INFLOWS:
Profit = Revenue-Cost
OUTFLOWS:
Invest_for_CE = Retained_earning*Investment_ratio/Investment_period
Target_profit(t) = Target_profit(t - dt) + (Target_profit_growth) * dt
INIT Target_profit = Initial_target_profit
INFLOWS:
Target_profit_growth = IF(Target_profit/Profit_adjustment_period>Profit*(1+Profit_growth_ratio)) THEN 0 ELSE Profit*(1+Profit_growth_ratio)-Target_profit/Profit_adjustment_period
Cost = Total_input_cost+Production_cost
Cost_per_new_recyclable_input = 30
Cost_per_polluting_input = 20
Environmental_cost_per_emission = 0.01
Environmental_management_cost = Pollution_emission*Environmental_cost_per_emission
"Initial_on-process_new_polluting_input" = 28e3
Initial_polluting_input_ratio = 1
Initial_polluting_input_stock = 10000
Initial_retained_earning = 2e7
Initial_target_profit = 1e6
Input_order_duration = 1
Input_ratio_reduction_gap = Polluting_input_ratio - Target_input_ratio
Input_reduction_to_investment_ratio = 5e8
Investment_period = 6
Investment_ratio = GRAPH(Required_investment/Retained_earning)
(0.000, 0.000), (0.200, 0.200), (0.400, 0.400), (0.600, 0.600), (0.800, 0.800), (1.000, 0.958), (1.200, 1.000), (1.400, 1.000), (1.600, 1.000), (1.800, 1.000), (2.000, 1.000)
New_polluting_input = IF((Target_polluting_input_usage+Polluting_input_usage)*Time_to_obtain_input>Polluting_input_stock+"On-process_new_polluting_input") THEN (Target_polluting_input_usage+Polluting_input_usage)*Time_to_obtain_input - (Polluting_input_stock+"On-process_new_polluting_input") ELSE 0
New_recyclable_input = IF((Target_recyclable_input_usage+Recyclable_input_usage)*Time_to_obtain_input>"On-process_new_recyclable_input"+Recyclable_input_stock+Recycled_input) THEN (Target_recyclable_input_usage+Recyclable_input_usage)*Time_to_obtain_input - ("On-process_new_recyclable_input"+Recyclable_input_stock+Recycled_input) ELSE 0
New_recyclable_input_cost = New_recyclable_input_delivered*Cost_per_new_recyclable_input
Polluting_input_cost = Polluting_input_obtain*Cost_per_polluting_input
Pollution_emission = (Polluting_input_usage*Pollution_emission_per_polluting_input)+(Recyclable_input_usage*Pollution_emission_per_recyclable_input)
Pollution_emission_per_polluting_input = 1
Pollution_emission_per_recyclable_input = 0
Product_output = IF(Polluting_input_ratio=1) THEN Polluting_input_usage ELSE Polluting_input_usage/Polluting_input_ratio+Recyclable_input_usage/(1-Polluting_input_ratio)
Product_price = 100
Production_cost = Product_output*Production_cost_per_unit
Production_cost_per_unit = 10
Profit_adjustment_period = 1
Profit_growth_ratio = .01
Profit_margin = IF(Profit>0) THEN Profit/Revenue ELSE 0
Recyclable_input_cost = Recycle_cost+New_recyclable_input_cost
Recycle_cost = New_recycled_input*recycle_cost_per_unit
recycle_cost_per_unit = 5
Recycle_ratio = 0.9
Recycled_input_usage_duration = 1
Required_investment = Input_ratio_reduction_gap*Input_reduction_to_investment_ratio
Revenue = Product_output*Product_price
Target_input_ratio = 1-STEP(0.1, 0)
Target_polluting_input_usage = Target_product_output*Polluting_input_ratio
Target_product_output = Target_revenue/Product_price
Target_recyclable_input_usage = Target_product_output*(1-Polluting_input_ratio)
Target_revenue = IF(Profit_margin>0) THEN Target_profit/Profit_margin ELSE Target_profit
Time_to_destock_input = 1
Time_to_obtain_input = 2
Total_input_cost = Recyclable_input_cost+Polluting_input_cost+Environmental_management_cost
{ The model has 64 (64) variables (array expansion in parens).
In root model and 0 additional modules with 0 sectors.
Stocks: 8 (8) Flows: 12 (12) Converters: 44 (44)
Constants: 22 (22) Equations: 34 (34) Graphicals: 1 (1)}

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