Cluster's growth and energy demand simulation model: A system dynamic approach

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Abstract

This paper simulated the growth of industrial cluster and the demand of its energy intensity by using the system dynamic modeling approach. For a specialized high-tech industrial cluster, its transaction cost as such energy intensity is inevitable as a factor that reflects long-term energy efficiency and the effectiveness of productivity cost. There is still no empirical finding about cluster growth and energy demand yet it is found that the more cluster's innovation, the more efficiency of energy factors, and the more effectiveness of a spillover of small-scale industry that change the new dynamic of the high- tech cluster.

Keywords:

Industrial cluster growth, high-tech cluster, energy demand, system dynamic, simulation

1. Introduction and motivation

Clustering becomes a key mode of economic concentration of specialized industries and a focus of economic development in cross-border and regional countries with full support of government policy. The world economy has pulled more intention of government enthusiasms to encourage the development of high-technological productivity in most industrial clusters of which aimed especially in innovative transaction sharing, technological regimes and specialized employment's spillovers. For a successful cluster formation has exclusively evolved by increasing an economic efficiency [1]. Whereas the key features of cluster's policy change dramatically in correlation between productivity efficiency, innovation spillover, and new linkages of transition economy [2]. Transition economies often focus on a mix industry types especially in developing countries and change from planned economy to market economy. On the other hand, developed countries are likely to invest in an advanced economy focusing on high-tech industries. Not surprisingly, those high-tech industries are considered as an attractive cluster in which government urged new supporting policy to pull various investment funds. These funds are also to create the collaboration incentives for cluster's members in high-technological sectors [3]. According to a Cluster Dynamics, clustering is a commissioning of gathering the relative members of knowledgeable firms that have the same quality of innovative productivities and process-linkage collaborations in their economic development [4]. These collaborative process linkages usually enable a vigorous level of an innovation transfer and other related technological activities through the production-change benefits. For the major improvement of the production changes in transitive economy, the declining energy intensity has been revealed by using a decomposition model [5]. This model showed a significant finding about the relativity of productivity's changes by using 4 factors as following; firstly, the importance of energy-intensive economy, secondly, the energy intensity of transportation industry and economic activities transitioning in agriculture, services, and residential industry, and thirdly the effect of structural change that has distributed to overcome its productivity's improvement and fourthly, the

declining of energy intensity itself. From their decomposition model, it reduced the energy use per GDP depended on the concerns of socioeconomic and environmental benefits that was considered as the market-based reform in economic focus of efficiency and the improvement of technology-based production.

The structure of this paper shows the descriptive result as follows: In Section 2 describes how the theoretical framework pointed out that a small-scale industry (SSI), as a member firm in cluster dynamic, is a crucial factor to change the effect of total energy intensity by gaining innovative spillovers and sustaining energy requirement in local industry cluster. In Section 3 simulating from the spillover of social capital that shows the development of new initiative SSI. In Section 4 presents the result of the causality of social capital and spillovers in energy efficiency requirement.

2. Cluster dynamics' simulation approach

Considering Cluster Dynamics as a complex system, the need to conceptualize the activities of cluster dynamics as a complex simulation model, the scopes of industrial cluster's development could be broken down into related-collaborating processes by using the activity-based transitions comprised of technological, economical, and sociological factors that were classified as the major loop of developing life cycle in our case-study derived from EU-10's cluster dynamic and its formation.

2.1 Cluster initiatives and formation

The background of a prospective Cluster Dynamics has focused in the local industries and the cluster's agglomeration that mostly reformed across regions among those diversified business's partnerships, extensively in transition economy. The influential work of Michael Porter (1990) has pointed out that his diamond model analysis was a new cluster initiative to global policy maker [6]. By examining, Porter's diamond model, there are concerning linkages of conditional factors that most local firm in a particular industrial cluster pursued to overcome its scarcity such as supply of natural resources. This study explicitly needed to find out the causality of energy intensity and the developing economy that focused in advanced activities about the technological-related innovation in industrial cluster. From Porter's model, it has derived some demanding conditions for local use of existing resources, so a cluster must interact with local labor market and a research university with which required to expand its technological upgrade for all regional productivities. This is how the regional industries involve in cluster formation and collaborative development to maximize the benefits of local presence. They must also foster a substantial regional investment and enhance the cluster's support from corresponding government bodies and others infrastructures such as utilities, schools, financial services, media, and research groups.

2.2 Cluster collaboration and barriers

For a cluster to grow, the main combination between regional firm members and their employments altogether as the social capital development that allows both formal and informal employment' s migration in regional cluster. This social migration helped cluster's firms commit in problem solving, collaboration, brainstorming, ideal patent development, skill and resource transfer. This evolution of cluster is so called "The dynamic of cluster's collaboration", Cluster Dynamics could be attracting to the new inflow of international market as an enormous inbound investment (FDI– foreign direct investment and VC – venture capital), import of materials, components and products, and new technologies [7].

For developing new technology and sustaining growth of clusters dynamic, it is crucial for a small scale industry (SSI) as a cross-regional cluster's member to easily get new technological knowledge and transfer its know-how specialized in developing new energy efficiency and improvement factor to overcome cluster's barriers [8]. They concluded the result of six important factors to effectively handle barriers of energy conservation; (1) technical – lack of availability,

reliability and knowledge of efficient technology, (2) institutional – lack of right technology input, financial support and proper program, (3) financial – lack of explicit financial mechanisms, (4) managerial – lack of training, improper managing, (5) pricing – lack of rational pricing of electricity and other fuels and (6) information – lack of appropriate information, information diffusion problems. They also revealed that financial initiatives and behavior of manageable entrepreneur are as important barriers as the improvement factor of energy efficiency. Though the priority to resolve all barriers are not similar among others industrial cluster, the financial inflow is the most important to enhance the improvement of energy efficiency. Moreover, related study of SSI's barrier in transition countries [9] found many optional interventions and policy to require a coordination of government bodies and commissioning agents to promote the energy conservation program in particular cluster.

2.3 Simulation of complex cluster model

For System Dynamics is a computer-aided simulation and an approach for analyzing and resolving a complex solution in policy making with the model of causality between the based case scenario flow of connectivities or the processing linkages and the feedback of condition formular specified in timely fashion, this simulation model also nested the set of dynamic results from the corresponding balance-loop of calculation. The matter of the fact that, "Industrial Cluster Dynamics" [10], the model derived from the work of Jay W. Forrester at the Massachusetts Institute of Technology, giving that System Dynamics has its origins in control engineering model and management; the conceptual simulation uses a dynamic loop of causality based on relationship of data flow feedback and delays to analyze the dynamic behavior of complex economic development, growth forecast, and social interaction systems. This paper will create the new model of system dynamics that is presenting the growth scenarios of the biotech industrial cluster and enabling the development of sociological activities. Besides the growth, Cluster Dynamics has been initiated by the formation of related-technological firm, so a model simulates the flows of cluster's activities related economic development. Expectedly, from simulation, an energy effective loop diagram of economic development could be generating the flow of energy intensity and demand thoroughly.

2.4 Cluster Growth and Energy Demand

During the period of the study, there are some comparative works between economic growth and energy consumption that studied an impact of related industry at the national level. Our challenge is to focus on regional, cross-border, and agglomeration of industrial cluster. Since the late 90's as the industrial cluster has been developing among emerging countries. Recently, our empirical research has been carried out as sophisticated Cluster Dynamics of which explained about the collaborative memberships with hi-tech patents and development via R&D institution that could have transferred the innovative knowledges to some others specialized SME. At times, a cluster has been supported by cluster committee has been imposed as management also the memberships must have the related innovative activities. Moreover, in transition economies, a cluster has been populated by regional social development with local firms' collaboration. By reinforcing economic activities and growth, most influential studies showed a supporting policy from government as such a crucial part in developing countries. The structure of long-term energy policy could be simulated upon a time series of 20 years from 1990 to 2011 that provided many empirical attributes from the hi-technological based biotech-industrial clusters. To evaluate the feedback of energy intensity or energy demand, some economical endogenous such as income and energy price are implicitly included with energy requirement as a factor of intervention as given by a government policy [11].

3. Methodology

3.1 Simulating a model between cluster formation and spillovers

The scenarios of industrial cluster from the transition state of economic development and its productivity output using of energy efficiency in which has been carried out from 20 years of 1991-2011 EU-10's cluster dynamic of 10 countries by conventional data collection from the business-as-usual researching and statistically evaluated as a focus-group observation [12]. Our model was conceptually reformed by initiating a cluster formation about the total number of local firms in 2012 with the causal loop of new 82,857 enterprises that generating total of 5,532,110 employments simulation model. In this case, we have to imitate the knowledge development and transfer to spillovers of new SME and SSI respectively. Although there was an absence of specific cluster's economic transaction activity, the Cluster Dynamics' co-flow development of SME and the know-how spillovers, as an endogenous factor in System Dynamics, [13] have been adopted in this model. However, the simulation in this paper needed to point out those correspondant factors as the endogenous set of co-efficiency parameters in our balancing loop from the major cluster's growth activities and the barriers of productivity's transaction cost given by energy factors as follows; energy intensity, energy efficiency, energy conservation.

Measuring and comparing those given barriers in particular cluster could be more challenging. Since most studies have been found with static scenarios, but this model was built to use an open-loop causality of cluster's activities and commissioning policies. It was about to simulate from the initiative of Cluster Dynamics and become a cluster formation and generate the growth development from knowledgeable employment. Until, the cluster growth expanded throughout the regional industries with the knowledge transfers and spillovers, this social development was level-up without directing the conventional parameters from other economic factors such as volume of productivities and profit [14]. To assess the growth of industrial cluster by using theoretical policy [7], an economic growth was leveraged with the set of comparison between the capital resources: FDI as the investment through increasing number of new SSI in cross-border and regional cluster, employment migration, private funding as SME's spillover, market demand and the social's private consumption to production innovation or increasing new collaborative patents. On the other hand, export, GDP, economic, productivity benefits are not presented to build a model because this paper tried to limit scope of specialized cluster formation with corresponding to the government policy in supporting local social development of knowledgeable employment and spillovers. That was mainly applied to develop specific EU10's cluster growth; in addition to, our most influential empirical study on causality between cluster dynamic and regional FDI to drive economic growth [13], it has already given in the model such government policy to leverage domestic capital with an initial delay of spillovers, migration and investment. The delay is concerned in this model, as a starting business activities and requirements to generate a periodical activity-based collaboration in cluster dynamic.

3.2 Perceived barriers in the causal loop model

It is necessary to understand all barriers and supporting factors in our main causal loop and their linkages of each cluster's activities. Among the main loop of simulation are comprised of cluster formation, economic transition activity, and energy intensity and requirement. The scenario of cluster formation loops in system dynamic modeling will be computed based on the observation in cluster dynamic linkages, derived from the empirical study of clusters' policy have shown causality between cluster growth and government policy [15].

3.3 Indication of the cluster dynamic model

Based on the EU-10 case study, this paper will be focusing the successful scenario for higher

number of enterprise, employment, high-tech patent collaboration with major developing countries. Clusters are part of regional economies in EU-10 developing countries across the subdivision of cross-border areas and also driving the collaborative development of regional innovation. There are set of indications that escalates major business infrastructure and focuses on the economic challenges that is concerned with competitors, the overall levels of employment skills, high-level infrastructure, and linkages of institutional capacity are as the potential reasons for the innovative performance gap and economic growth.

Moreover, clusters at the top ranking innovation leader in developed countries share the composite innovation indicator as a number of national strength of the innovation system, with the keys of economic activities and public-private business's research collaboration. EU-10's Innovation Union Scoreboard 2011 indicated very low shares of researching innovator or organization innovation as well as introducing product or process innovation by SMEs. However, there are number of growth rate of modest and moderate innovators that performed a convergence process as EU-10 catching-up leader [9]. On the other hand, this paper tries to analyze the hypothesis that SMEs could be promoting innovation linkage to energy efficiency in small-scale cluster initiative.

For international countries comparison with the EU, a selected group of major global competitors have been increasingly dominating the global innovation leaders; EU-27, US, Japan and South Korea have been well captured high growth in business activity and public-private cooperation, R&D expenditure, public-private co-publication, license and patent revenues from abroad and PCT patent application.

3.3.1 Structure of cluster dynamics

The main model structure of this simulation will be divided into 3 simulation scenarios: firstly, cluster formation to the spillover of small-scale innovative industry, secondly, employment to specialization and thirdly, energy requirement to energy demand.

3.3.2 Formulation & simulation

For these simulation scenarios that are the cluster formation, starting from the input flow and stock of "CE Industrial Cluster" the aggregation of same local firms in which have been leveraging their business cost of activities with innovative processes of collaboration. For instance, they join the cluster because they need the benefit from common share of high-tech infrastructure. The most important in development process, they prefer to gain rich resources from knowledgeable employment to help boost their innovative production with the export of business research and patent to upgrade all supplier partners as in the Porter's diamond model. Though the knowledge spillover helped new SMEs lower their technology startup cost of the investment; eventually, small-scale industrial cluster will upgrade their research development to higher technological platform and transfer to a new level of high-tech industrial cluster. By this stage, a cluster will become more dynamic to aggregate, the other innovative partners of "CE High-Tech SSI" within the same industrial cluster so called "CE High-Tech Cluster".

4. Causal loop and scenarios

From based-case empirical study as most cluster initiation has been supported by the government's policy. Our first scenario has explicitly promoted the factors of energy efficiency in new industrial SME as a small-scale cluster. Since government policy is one endogenous initiator of any cluster dynamic.

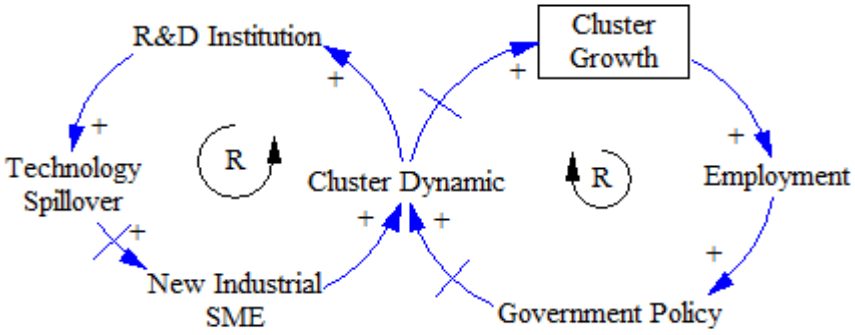

Fig. 1 Casual loop diagram showing the formation between cluster growth, socioeconomic development and spillovers of specialized SME.

Apparently, In causal loop diagram shows 2 main cause-effect loops as follows; As 1st right loop is the reinforcing loop comprised of all plus signs (+) in supporting linkage stated by R-loop that all innovative member firms has been agglomerated into a cluster that aimed to increase the capabilities of knowledge transfer to all employments, Meantime, the larger the proportion of employment development in one regional, the higher the support policy from enthusiasm government that aimed to increase the collaboration of new cluster's expansion in all regions. As 2nd left, reinforcing loop R-loop comprised of all collaborating partnerships that creates the new spillovers with technology development.

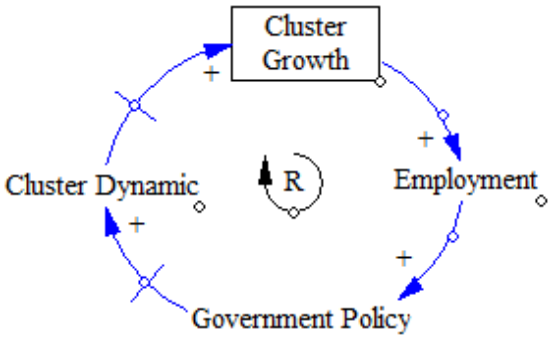

Fig. 2 Reinforcing loop between cluster dynamic, employment, and government policy.

This initiated from the rectangular stock of cluster growth as the main loop in, which provides 2 substantial reinforcing loops of R - loops. We interpreted that the positive co-flow of cluster dynamic formation of collaborating partner is reinforcing the economic activity growth as the main input transition from cluster growth and employment development by government policy support itself. This will reinforce cluster's employment as the higher the employment ratio, the more cluster supported by government policy.

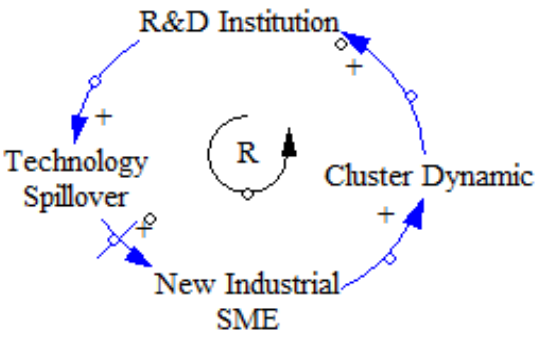

Fig. 3 Reinforcing loop between R&D institution, technology spillovers, new industrial SME and cluster dynamic.

Next co-flow loop of reinforcement is derived from the factor of endogenous cluster dynamic by which all collaborating partners are growing together as long as the initial development in first R- loop of cluster growth. As cluster becomes more successful, it promotes collaboration in associate with the R&D institution for particular innovative transaction processes. This also initiates innovative benefit feedback to the co-flow of cluster dynamic in term of technology spillovers for newcomer as specialized SME.

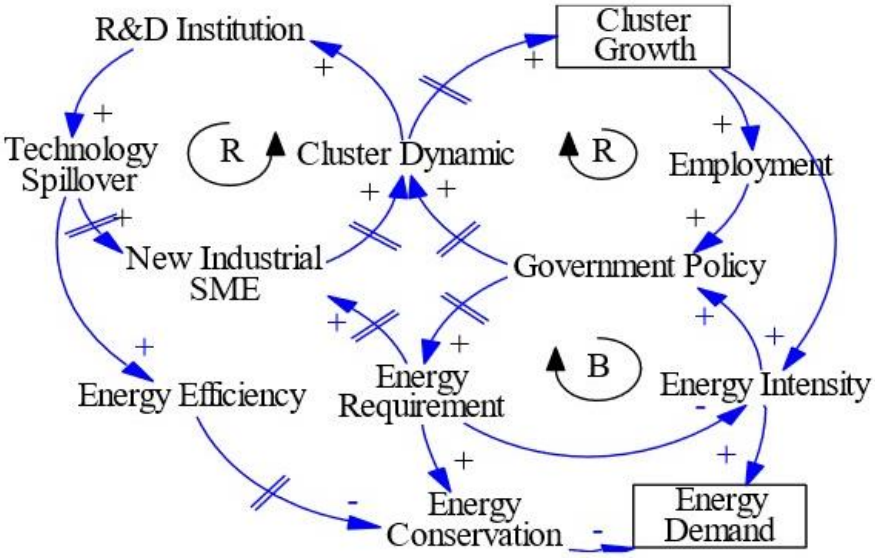

Fig. 4 Causal loop of energy factors affecting government policy.

The next major causality of balancing loops is a nested loop among energy factors; the change in energy requirement will cause bidirectional effects of other energy conservation, energy consumption, energy price, energy import, energy demand, energy supply, energy intensity, and energy efficiency. We believe that this latter causal loop will drive government policy to stimulate energy conservation, but a delay loop of one another energy requirement in which shows an important balancing loop between economic factors based on economic growth and energy consumption as crucial feedback effects to government policy. If we add a scenario that the government focuses directly in energy requirement policy, it shows that energy conservation will be affecting energy demand directly through energy conservation and indirectly delay affected through energy efficiency that will motivate a specialized SME with its high-technology research to leverage this government's new energy requirement.

5. Cluster model

The model is composed by 3 main modules of stocks and flows as follows; clusters' enterprise, clusters' employment, and energy demand.

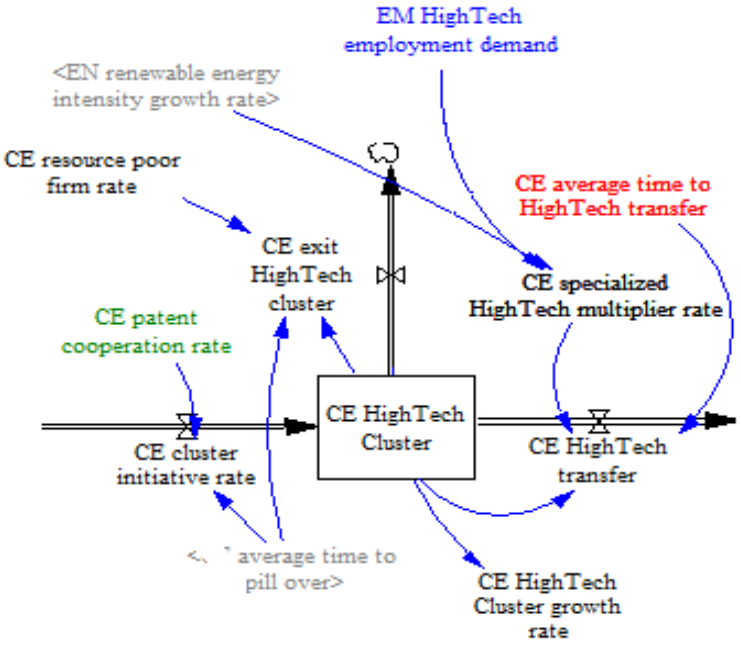

Fig. 5 Cluster formation causal loop and co-flow with Employment causal loop.

Fig. 5 shows the first main module explicitly how a cluster has been agglomerated within the same specialized firms. However, firms could alternatively enter into and exit from particular cluster when they develop and grow by the higher rate of collaboration among each initiative firms in the high-tech cluster. On the other hand, non-performing firms, that fail literally from cluster collaboration and barriers, will eventually exit the cluster. So the higher rate of effective specialization among high-tech cluster, the more knowledge transfer to potential employment will gradually help cluster expand with new spillovers as a small-scale entrepreneur or SME.

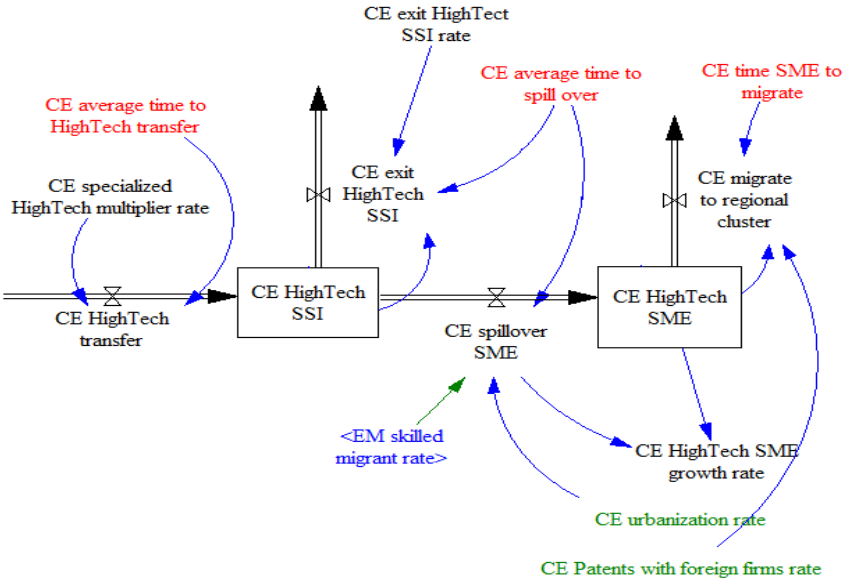

Fig. 6 Cluster initiatives and high-tech spillover.

As cluster initiatives always develop the new high-tech specialization to a small-scale industry as shown in Fig. 6. In addition, there is still enthusiasm in cluster development by giving R&D institution in all specialized clusters that focus to give knowledge transfer with new high-tech spillovers. However, this cluster's knowledge spillovers also contributed to its migrant employment and spread out to others cluster regions as SME migrants and spillovers.

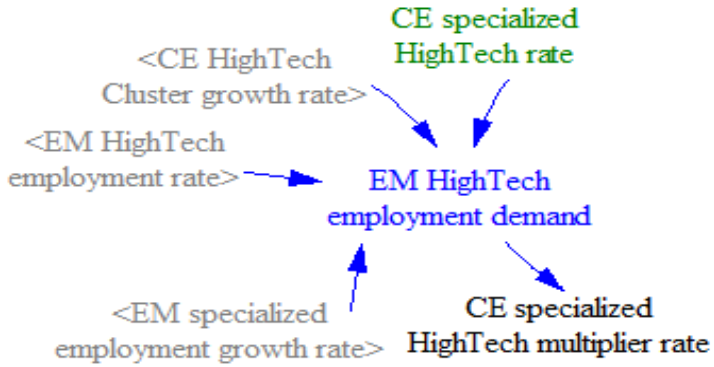

Fig. 7 Cluster's high-tech spillovers contribute to new specialized high-tech SME and cluster dynamic.

The co-flow development of both modules in first Cluster formation and second specialized Employment as shown from Fig. 7 is the growth rate of new diversified or a new focus high-tech specialized SME and a small-scale industrial cluster.

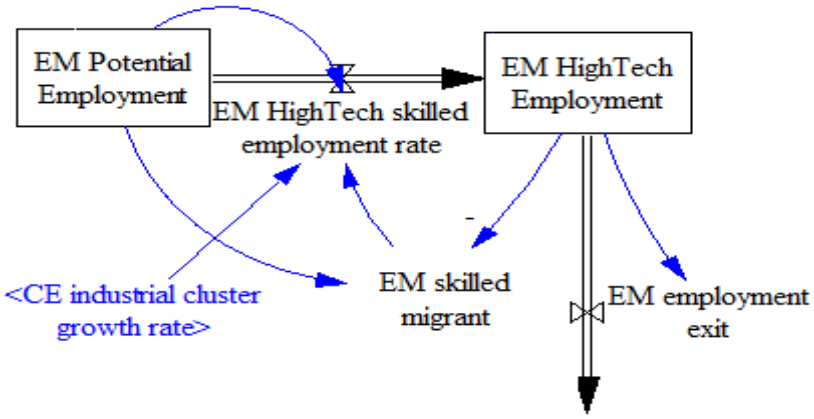

Fig. 8 Cluster employment and skilled knowledge transfer.

By Fig. 8 above and Fig. 9 below explains the model of both cluster enterprise and employment's co-flow of growth as the higher ratio of new cluster development with the higher rate of corresponding growth of specialized SME and specialized employment within that specialized cluster, the more spillovers contributed to the others cluster's expansion in regional initiatives as cluster dynamic.

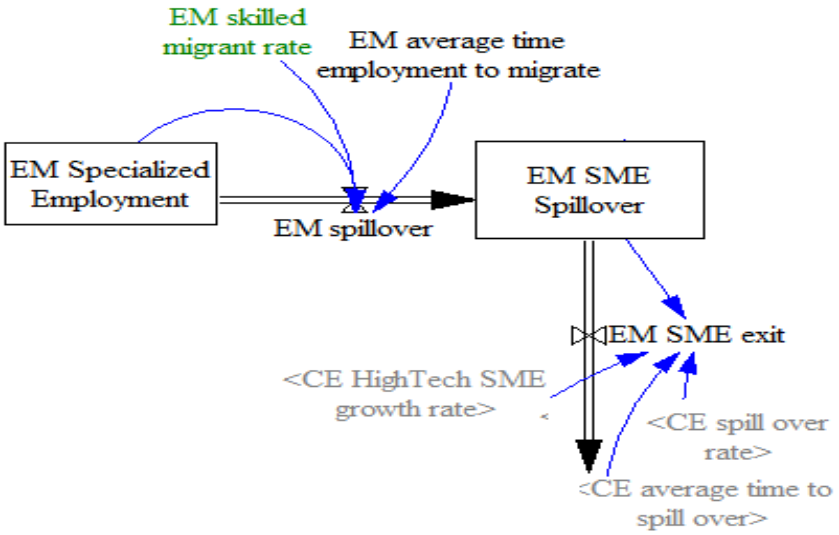

Fig. 9 Clusters' employment spillovers to migrant.

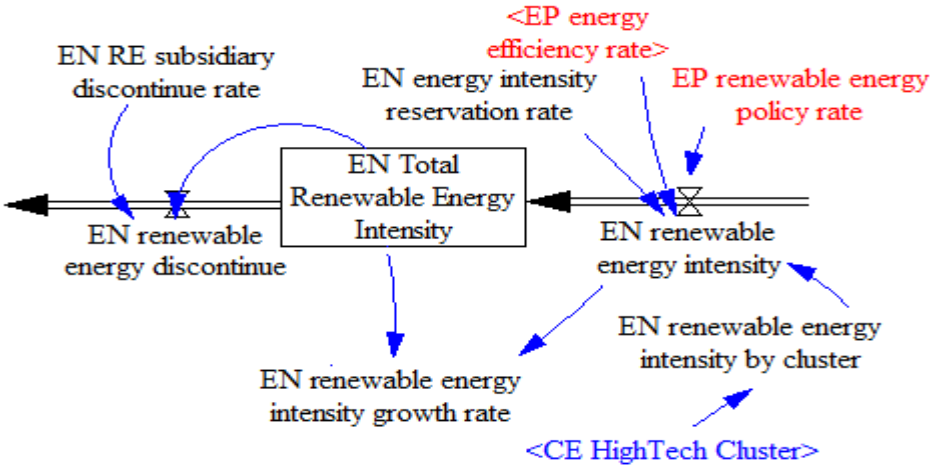

Fig. 10 Cluster's growth and Energy Demand Co-Flow.

Fig. 10 simulated the cluster's demand for renewable energy intensity by which government contributes the great advocacy in energy policy and renewable energy requirement to develop in cluster initiatives. However, the demand of conventional energy intensity still remained, but there is government's enthusiasm to change overall industry's energy conservation and efficiency. We assume and impose the energy efficiency policy rate of which would encourage high-tech cluster decrease its demand for conventional energy intensity; in the meanwhile, SME took the challenge to increase more energy efficiency and become more specialized in high-tech industrial cluster. However, the cluster is still demand for energy efficiency and innovative development followed by government's energy requirements and policy.

6. Results and discussion

In this model, the causal loop diagram shows energy consumption pattern based on energy requirement that has been stimulated by government policy through the development of cluster dynamic in which leveraging the innovation of energy intensity and energy efficiency. Besides, the bigger energy efficiency, the smaller energy conservation has been accounted based on higher energy requirement.

It's important that government policy has been manipulated to drive cluster dynamic with merging infrastructure. By this reinforcing loop, significantly bridging of regional location has emerged new industrial SME associated with R&D institution. Hence, cluster growth directly promotes considerable employment, technology spillovers, higher GDP and finally boosts economic growth.

Industrial SME shares major accounts for innovative development of energy intensity. This would have macro benefits as well in the form of reduced energy demand or reduced demand growth for energy conservation or energy demand from industry. This analysis lends credence to argue that energy intensity makes a difference to their energy performance in term of returns on economic efficiency; it would escalate economy transition to achieve higher productivity and therefore greater economic cost-efficiency.

7. Conclusions

There is a positive relationship between the growth of industrial cluster and higher conventional energy intensity on which a delay of 2 years of government policy to boost renewable energy requirement. This also showed a positive causal of cluster growth and energy efficiency and the balancing feedback of reducing conventional energy intensity while economic efficiency are being leveraged by specialized spillover of high-tech SME. The more positive support of renewable energy policy to attract most specialized SME across regions, the higher technology transfer that helps high-tech industrial cluster gain a lot more energy efficiency to reduce conventional energy intensity, and to increase higher renewable energy and conservation in the form of new energy requirement. Hence, it's more flexible for a small-scale industrial of high-tech cluster to leverage new requirement from policy makers to improve the energy efficiency and reduce the energy-intensity.

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