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The Dynamic Structure of Clusters: Characteristics and Dimensions

Case in Point: IT cluster in Bangalore, India

Introduction

During the last decades, scholars and business people have started paying more attention to industrial clusters. Companies all over the world have started to recognize the benefits of industrial clusters. Clusters have been used on a national level, but they have also been the target of FDI. While the role of clusters in promoting industrial development has been increasingly recognized in the literature, the locational choice of industrial clusters has rarely been analyzed. The underlying factors affecting the choice of location for industrial clusters have also been missing a more intense scrutiny, particularly in the context of industrial development in developing countries. This paper will present the idea of clusters from Michael Porter's perspective, and bringing together literature regarding the choice of location for industrial clusters, the final goal of this paper will be to create a dynamic system model of an industrial cluster and the factors affecting its location and thus, its evolution.

Background and Literature Review

In 1890, Alfred Marshall (1925) claimed that firms cluster to economize on the transport of goods, people and ideas. Adapted to today's world, these three reason for economic agglomeration can be seen as: availability of intermediate/final goods, labor market pooling, and technology spillovers. (Duranton, 2001)

During the last decades, globalization brought many changes in technology and competition and spread them around the world. These changes in technology and competition have "diminished many of the traditional roles of location". (Porter, 2000)

Even with globalization increasing the speed of technological changes and spread around the world, even with globalization enhancing competitiveness, we cannot fail to notice that industrial clusters are present in all level of business in any national, regional, state or metropolitan economy.

Michael Porter (2000), who has been credited with popularizing the term cluster, defines cluster as *"geographic concentrations of interconnected companies, specialized suppliers, service providers, firms in related industries, and associated institutions (for example, universities, standards agencies, and trade associations) in particular fields that compete but also cooperate"*

Many authors have presented different ideas about clusters. Martin and Sunley (2003) present ten different ways of defining clusters. One typical alternative definition sees a cluster as "a spatially limited critical mass (that is sufficient to attract specialized services, resources, and suppliers) or companies that have some systematic relationships to one another based on complementarities and similarities." (Rosenfeld, 2002) Doeringer and Terkla (1995) define clusters as a "geographical concentration of industries that gain performance advantages through co-location."

Most of the definitions used are conceptual and descriptive, not analytic and precise. Therefore, even if some of the authors agree with some of the ideas in defining clusters, most of the disagreements are found in the applications to a particular region or industry.

Joseph Cortright (2006) argues that the disagreement between different authors in defining clusters is due to the very disparate purposes for which the concept of a cluster is used: used to organize local economic development efforts, develop empirical analyses of local economies, and theorize about regional economic growth. (Robinson, 2002)

Jacobs and DeMan (1996) join in the discussion about defining clusters, arguing that "there is not one correct definition of the cluster concept...different dimensions are of interest." What Jacobs and DeMan are trying to do is to identify some key factors that could define a cluster and its behavior. They include the geographic or spatial clustering of economic activity, horizontal and vertical relationships between industry sectors, use of common technology, the presence of a central factor/character/actor, and the quality of the firm network, or firm cooperation.

A way to understand clusters would be to follow Jacobs and DeMan's idea, and accept the fact that there are multiple dimensions to cluster relationships, including geography, social distance, technology and production flows. Corthright (2006) argues that clustering is about proximity meaning that business that are closer to one another have advantages that are unavailable to businesses that are farther away.

Porter (2000) argues that what happens inside a company is very important, but we should not overlook the importance of the immediate business environment outside the company.

Doeringer and Terkla come up with other factors that contribute to the evolution and development of clusters, trying to define what a cluster is. Some of the factors overlap with previous authors' ideas: lower transportation and transaction cost, access to skilled labor force, fast information, knowledge and technology transfer among companies. All these factors will lead to new industry growth. Another important factor in the evolution of clusters: face-to-face interaction. Local proximity to firms in all aspects of the production process, such as the suppliers, machine builders, assemblers, distributors, and final customers allows the cooperating firms to adopt new technology and innovations rapidly, therefore increasing the overall efficiency of the production process.

Michael Enright (2002) looks at the question of what dimensions influence when firms should choose to either compete or cooperate. Levels of competition and cooperation vary by industry and region, but in general cluster firms can benefit from cooperation on industry-specific activities while competing on company-specific levels. Michael Enright uses eleven dimensions and characteristics to analyze clusters, while in presenting the evolution or development of a cluster, he five categories which indicate where efforts should be directed in the cluster promotion process. He also discusses the importance of face-to-face communication in the innovation process, and attributes cluster growth to incentives, capabilities, and pressures to innovate within the local environment.

With all these definitions and dimension of clusters, and given the widely different uses of clusters, confusion is unavoidable in the literature that looks at industrial clusters. It is impossible to agree on one definition that can be considered universal. However, there is a very good possibility to gather and agree on a range of characteristics (dimensions) that describe and classify industrial clusters.

This paper will try to dissect Michael Porter work on clusters and present all the dimensions put forward by him. It seems that Porter cluster characteristics include most of the characteristics and dimensions presented by most of the authors presented in this paper. The second part of this paper will look at system dynamics and the reasons behind constructing a system dynamics model to look at the different dimensions of clusters. The third part of the paper will present a complete Michael Porter model, while the forth part will zoom on that model, taking one of these dimensions (labor) and trying to analyze the relationship between the cluster and this particular dimension.

Basic Cluster Model

The following three parts of this paper can be views as a journey staring outside a cluster and finishing inside one of the many dimension of a cluster. First, a simple dynamic model of a cluster will be presented, without focusing on any characteristics or dimensions. Then, this simple dynamic model will blossom into a full grown model that will include all of Michael Porter's characteristics and dimensions of a cluster. Third, the dimension of labor will be taken into consideration and another model will present that relationship between a cluster and labor.

In order to understand why system dynamics was chosen as a method to model the structure and behavior of clusters, it is very important to understand the concept of dynamic complexity, or when this dynamic complexity arises. Considering a cluster to be a system, and applying John D. Sterman's principles of dynamic complexity we can obtain the following:

<<TABLE 1>>

Following Sterman's (2000) principles, it holds true that industrial clusters can be considered complex dynamic systems.

Model 1 shows us a cluster and the two major influences that shape the cluster: the firms entering the cluster and the firms exiting the cluster. Of course, the firm entry and exit rate are influenced by certain effects which increase or decrease the two rates, based on the dimensions and characteristics of the cluster and also on the evolution of the cluster.

The effects on firm exit rate and the effects on firm formation rate are mostly different in composition, but depending on the cluster we can find some similarities as well.

<<MODEL 1>>

Mertz and Groothuis (2006) developed a similar model and showed that when a cluster approaches capacity firm formation rate is much higher than firm exit rate. Assuming that the model can only sustain a limited number of companies, once the cluster reaches capacity, firms tend to enter in the cluster at a similar rate as they exit the cluster. When the cluster goes over its capacity the number of firms exiting the cluster tends to be larger than the number of companies entering the market. Mertz and Groothuis argue that the equilibrium in such a cluster will be reached somewhere just below capacity.

Model 1, as well as Mertz and Groothuis's model, does not look into deep at the dimension of the cluster and at what characterizes a certain cluster. In order to fully understand how clusters affect the firm formation rate and the firm exit rate, a more detailed look is needed. Thus, taking Michael Porters work on clusters, a certain number of characteristics and dimensions have been determined. The application of those characteristics and dimensions to Model 1 is the next step in this paper, producing Model 2: Michael Porter Cluster Structure Model.

Integrated Porter Model : Michael Porter Cluster Structure Model

From Michael Porter's work a couple of main ideas can be seen throughout. Cluster include distribution channels and customers, manufacturers of complementary products, companies related by skills, technologies or common inputs, linked industries, suppliers of specialized inputs, machinery services and specialized infrastructure, related institutions such as research organizations, universities, training entities, standard-setting organizations.(Cortright, 2006) Michael Porter (2000) considers that the industrial cluster is the product of the four factors that make the "diamond of competitive advantage": factor conditions, demand conditions, related and supporting industries, and firm strategy, structure and rivalry.

<<FIGURE 2>>

One of the most important arguments that Porter (2000) is circulating in his papers is the fact that without competition a cluster will fail. He agrees that competition and cooperation both exist in clusters, but on different levels and dimensions, so they can co-exist because they affect different players. Cooperation is on a vertical dimension, involving companies in related industries and local institutions.

Clusters not only thrive on competition, but they also affect competition, creating thus a cycle, self reinforcing, which promotes the growth of the cluster. Competition in clusters will provide increased productivity for the companies in the area, will be driving the direction and pace of innovation and will stimulate the formation of new businesses, which expand and strengthen the cluster itself.

Clusters allow companies to benefit as if they had a greater scale, or as if they joined formally, without requiring them to sacrifice their flexibility.

All of Porter's arguments about clusters are driven by one idea, the idea that companies (and countries) want to increase their productivity, because that is what determines the prosperity of any company or country.

According to Porter, cluster can be very influential in increasing productivity due to a number of factors. A cluster would provide a better access to employees and suppliers. Specialized and experienced employees will be attracted to clusters, so it would be much easier for companies in the cluster to find such personnel. Also, workers would be willing to relocate because of the job security being higher in the cluster than in other companies. The presence of suppliers in the cluster will provide a lower cost of transportation for companies, and will also allow for an easy support service.

Productivity will also be increased by access to specialized information, by access to institutions and public goods. Companies in cluster usually are better motivated than companies outside clusters. Although is hard in the beginning for managers to grasp the concept that competition is a major good force in clusters, with time they realize all the benefits that clusters bring to the table.

Complementarities are another factor that influences the productivity of the companies in the clusters. For example, the leather clothing clusters in Italy do not sell only leather clothing, they also produce and sell other kind of products complementary to leather clothing: bags, belts, shoes and others. The presence of companies which produce complementary products in a cluster offers a boost to the cluster and to the productivity of the companies in the cluster. (Porter, 2000)

Increased vertical integration occurs as the division of labor gets more specialized, and new firms are able to fill the new niche markets. Horizontal clustering occurs as the new technology and labor skills are applied to related industries in different sectors.

According to Porter, the most important factor that drives cluster development is competition. As it was shown earlier in the paper, Porter talks about competition between rival firms in the same cluster as the driving force for growth. This forces firms to be innovative, to improve and to increase their technology developments. Once a cluster begins to form, a self-reinforcing cycle promotes its growth, especially when local institutions are supportive and local competition is vigorous.

However, eventually a cluster faces decline. Some of the reasons why clusters decline are: technological discontinuities, a shift in buyers needs, restraints to competition (overconsolidation, mutual understandings, cartels), quality of institutions (can stagnate), and groupthink. But if competition inside the cluster does not die, Porter believes that companies can rally and survive any other problems. (Porter, 2000)

The dynamics of the evolution of a cluster can be modeled using system dynamics approach. The following model has been created to demonstrate this.

<<FIGURE 3>>

While it includes all the characteristics and dimensions of a cluster, this is just a visual static model. The model has a labor, competition, innovation, institution and technology submodels. These complex dynamic systems are difficult to grasp and to simulate. Therefore, in order to understand how the model works and in order to start to create a path towards simulation, it is helpful to split the model into its submodels. The next part of the paper will take a look at labor and the relationship between labor and an industrial cluster.

Labor Model

The modeling of Porter's idea of a cluster could create many misunderstandings. While the big model presented earlier it is very accurate in expressing Michael Porter's view of industrial clusters, we decided to take a closer look at some of the elements in the model and to try to simulate their effect on the cluster. Thus, we are starting with labor, because labor is a very important factor in the life of industrial clusters.

Imagine taking a magnifying glass and pointing it towards the labor branch that is found in Porter's model. Here is the model that we came up with, model that simulates the effect of labor on an industrial cluster.

<<FIGURE 4>>

The model assumes that the cluster has a finite capacity for firm. In the model the cluster is shaped by the Firm Formation and by Firm Exit, together with Additional Firms and Initial Firms in Cluster. This last variable is very helpful in running the simulation because it is a level variable, which can be fixed on a certain value or which can slide between certain values. This will give us an idea of any differences in the dimensions of the dynamic cluster when the initial number of firms in the clusters differs. The Additional Firms variable introduces more of the dynamic aspect of the model by including a number of companies that will enter the cluster based on different decision, different than labor cost. The Labor Cost variable gives us a cost of labor, while the Labor Cost Rate is the conversion of the Labor Cost into a variable that can be directly included into the Firm Formation and also a variable that can make connection between Firm Exit and Labor Cost.

As expected, and as shown in Model 1, the cluster evolves until a certain point, point where the certain resource(s) in use (in our case: labor) becomes too high and the productivity of the cluster is starting to go down. Fewer companies are entering the cluster now, while more are leaving. For more details about the model, equations and variable values, please see Appendix 1.

<<FIGURE 5>>

Once labor cost becomes unproductive, there is a very steep fall in the number of companies that are joining the cluster. A very interesting result of this model is that the number of companies exiting the cluster is not actually going up, but down and not in a fast way, but rather slowly following closely the evolution of the cluster. We also notice that in long run, the system tends to balance out, still keeping a certain number of companies inside the cluster, but having more or less the same number of companies joining and exiting the cluster.

<<FIGURE 6>>

<<FIGURE 7>>

In theory, the higher productivity associated with clusters should be associated with high wages for workers in the cluster. Specialization that can occur only in a cluster, matching certain skills to precise work and knowledge spillover should make the labor force in clusters more productive than the labor force outside the cluster. This would mean higher wages for cluster labor force. There are not many studies that look at the relation between clusters and wages.

Wheaton and Lewis (2002) found positive correlations between industrial and occupational specialization and wage levels. For a typical metropolitan area, a doubling in

employment concentration in a particular industry is associated with a 2% increase in wages. In our model we use a 1.5% increase in wages.

Another research finds that wages for workers in industry clusters were about 6 percent higher than for workers in the same industry in a nonclustered location. (Gibbs, 1998)

In order to see if Labor Model is anywhere close to reality, an application of this model to a real cluster should be the next step. In the next part of the paper, the Indian cluster of Bangalore will be presented and the relation between labor and the cluster will be analyzed.

Globalization and the Labor Force in Bangalore

The globalization of the IT markets has lead to deepening of the labor markets, meaning that the market increasingly extends itself to new areas of human activity. As markets grow, specialization takes place and the demand and supply for certain skills increases. In India the development of the IT labor market has been driven by the integration of IT-related activities globally. (Chandra, 2007)

The IT sector in India is also getting diversified in terms of domain. More people with different skill-sets and educational background can participate in the different IT labor markets.

Bangalore is the top ranking IT cluster in the country. There are a lot of good engineering and other professional colleges. These educational institutions attract students from all over the country creating a very vibrant student community and a very large talented labor pool. The growth of the bio-tech segment of the Bangalore cluster (80 firms) has been facilitated by the many research and teaching institutions and the large number of highly regarded potential work force. Overall Bangalore covers IT and biotechnology but also telecom and machine tools.

In 2004–05, the Indian offshore IT and business-process-outsourcing industry will generate approximately \$17.3 billion in revenues and employ an estimated 695,000 people. By 2007–08, that workforce will consist of about 1,450,000 to 1,550,000 people, and the industry will account for 7 percent of India's GDP. (Diana Farrell, 2005)

In the country's most popular offshoring locations, such as Bangalore, rising wages and high turnover among engineers—the professionals most in demand for IT services—provide evidence that local constraints on the supply of talent already exist. Wages for India's graduate software engineers have already risen steeply in the most popular offshoring destinations, such as Bangalore and Mumbai.

In the country as a whole, middle managers are also becoming scarce. Although India has more of them than other offshoring destinations do, the country also has higher demand because the offshoring sector has grown so fast: over the past decade, the number of middle managers it employs has expanded by more than 20 percent a year, and even more briskly in some cities. New entrants often lure qualified managers from existing businesses instead of training their own. Sometimes they poach across borders as well—Russian entrepreneurs, for example, have hired middle managers from India. Rapidly rising remuneration is evidence of their scarcity. Annual wages for project managers in India's export-oriented IT sector, for instance, have increased, on average, by 23 percent annually over the past four years, while the salaries of programmers have risen by 13 percent. (Diana Farrell, 2005)

<<FIGURE 8>>

It seems that clustering creates advantages at first, but those advantages disappear if the demand for talent, for specialized work force is bigger than the supply or if the infrastructure investments take longer than predicted. Companies should not get worried about all these, but they should start looking into other places that can offer enough supply of work force to exceed demand.

A McKinsey research shows that India has the lowest labor cost for university-educated employees of 16 potential offshore countries that were studied (roughly 12 percent of the US cost, on an hourly basis). India's graduates also work the longest hours—on average, 2,350 a year, as compared with 1,900 in the United States and 1,700 in Germany. (Diana Farrell, 2005)

Even with the increase in wages in India, it seems there is no necessity yet for getting worried. The McKinsey Quarterly projects that average wages for young professionals in service jobs in India probably will not exceed 30 percent of US levels, because of competitive pressures: when average Indian wages reach that threshold, companies will try to employ graduates from countries with lower or comparable wages. Supply from these countries will satisfy all likely demand for the foreseeable future. Our Model 2, the Labor Model shows that when a certain level for labor cost is reached the number of companies exiting is larger than the number of companies entering the cluster. The fact that the clusters continue to work and even balance out after a while is an outcome that confirms Diana Farrell's research presented in the McKinsey Quarterly report.

Conclusion

Although the Michael Porter Model it is too large still to be simulated, this paper has looked at the dimensions of labor cost and simulated a model that has shown some of the relations between labor cost and industrial clusters.

The interesting discovery of this model is that even if the wages are going up too much, the number of companies in the cluster will decrease to certain, balanced level at which will stay. Although it has been shown in numerous occasions that and in theory has been written a lot about the fact that clusters should devolve if one of the resources is not being used in a productive way, our model shows that it is not quite so. The reason for this is that once the labor costs get to a certain level, companies will not change location, but will bring in people from neighboring cheaper places or they will re-offshore, keeping everything running in one place and taking advantage of the cheaper labor in another.

For future research, in order to understand the idea of cluster and to create a common ground when talking about clusters, a further modeling of the other characteristics and dimension of the Porter Model is necessary. This will shed light on some of the misconceptions about clusters while providing strong evidence and information about the relationship between clusters and their dimensions.

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Appendix 1

- (01) Additional Firms= INTEG (Additional Firms*0.003,2)
Units: **undefined**
- (02) Cluster= INTEG ((Firm Formation+Additional Firms-Firm Exit),
initial firms in cluster)
Units: **undefined** [0,?]
- (03) FINAL TIME = 200
Units: Month
The final time for the simulation.
- (04) Firm Exit= (0.03*Cluster)
Units: **undefined**
- (05) Firm Formation= 0.05*Cluster-Labor cost rate
Units: **undefined** [0,?]
- (06) initial firms in cluster= 25
Units: **undefined**
- (07) INITIAL TIME = 0
Units: Month
The initial time for the simulation.
- (08) Labor cost= INTEG (Labor cost * 0.018,5)
Units: **undefined** [1,?]
- (09) Labor cost rate=IF THEN ELSE(Labor cost<15, Firm Exit*0.1, Firm Exit*1.5)
Units: **undefined**
- (10) SAVEPER = TIME STEP
Units: Month [0,?]
The frequency with which output is stored.
- (11) TIME STEP = 1
Units: Month [0,?]
The time step for the simulation.

TABLE 1

	<i>Dynamic Complexity</i>	<i>Cluster System</i>
Dynamic	Change occurs	True
Tightly coupled	Actors in the system interact strongly with one another and the rest of the world	True
Governed by feedback	Decisions alter the state of the world, causing changes in nature and triggering other to act, this giving rise to a new situation which then influences the next decision	True
Nonlinear	What happens locally in the local system often does not apply in distant regions	True
History-dependent	Path dependence, many actions are irreversible	True
Self-organizing	The dynamics of the systems arise spontaneously from their internal structure	True
Adaptive	The capabilities and decision rules of the agents in complex systems change over time	True
Counterintuitive	In complex systems cause and effect are distant in time and space while we tend to look for causes near the events we seek to explain. Attention is drawn to the symptoms of difficulty rather than the underlying cause	True
Policy Resistant	Complexity of the systems in which we are embedded overwhelms our ability to understand them.	True
Characterized by Trade-offs	Time delays in feedback channels mean the long-run response of a system to an intervention is often different from its short run response	True

Table 1: Dynamic Complexity of Industrial Clusters

Model 1

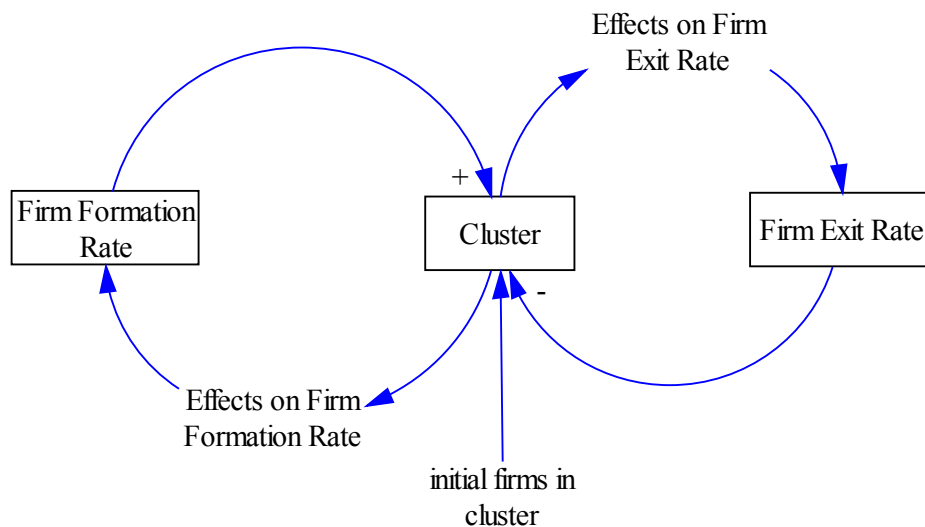


Figure 1: Model 1- basic model

Figure 2

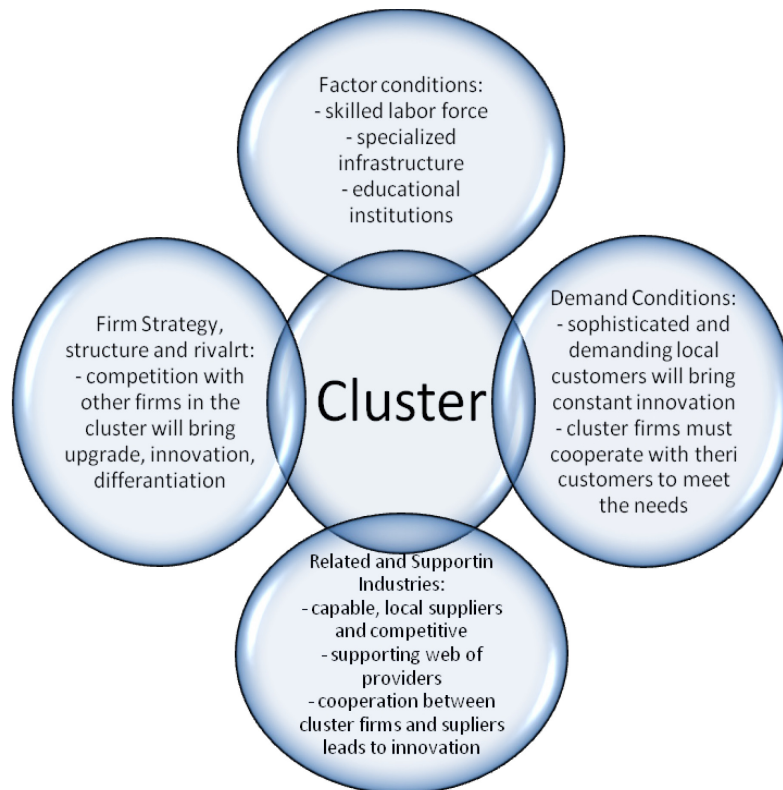


Figure 2: Porter Diamond of Competitive Advantage

Figure 3

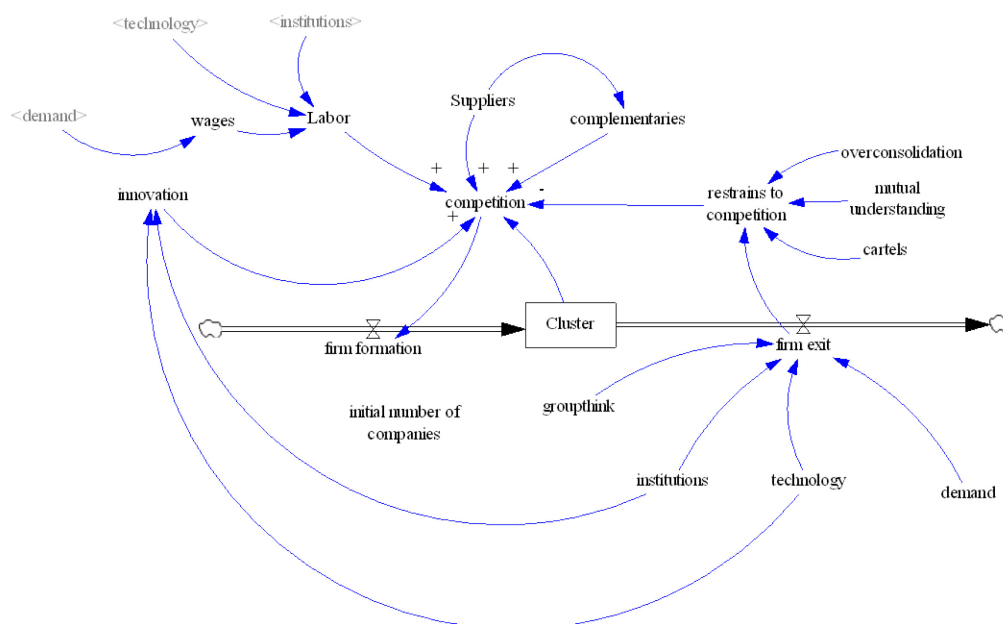


Figure 3: Michael Porter's Integrated Model

Figure 4

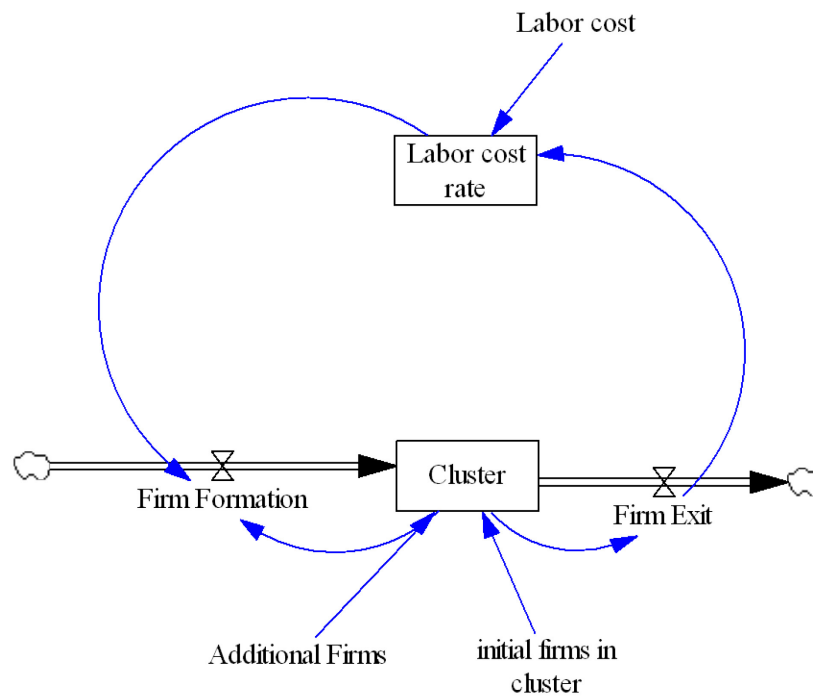


Figure 4: Labor Model

Figure 5

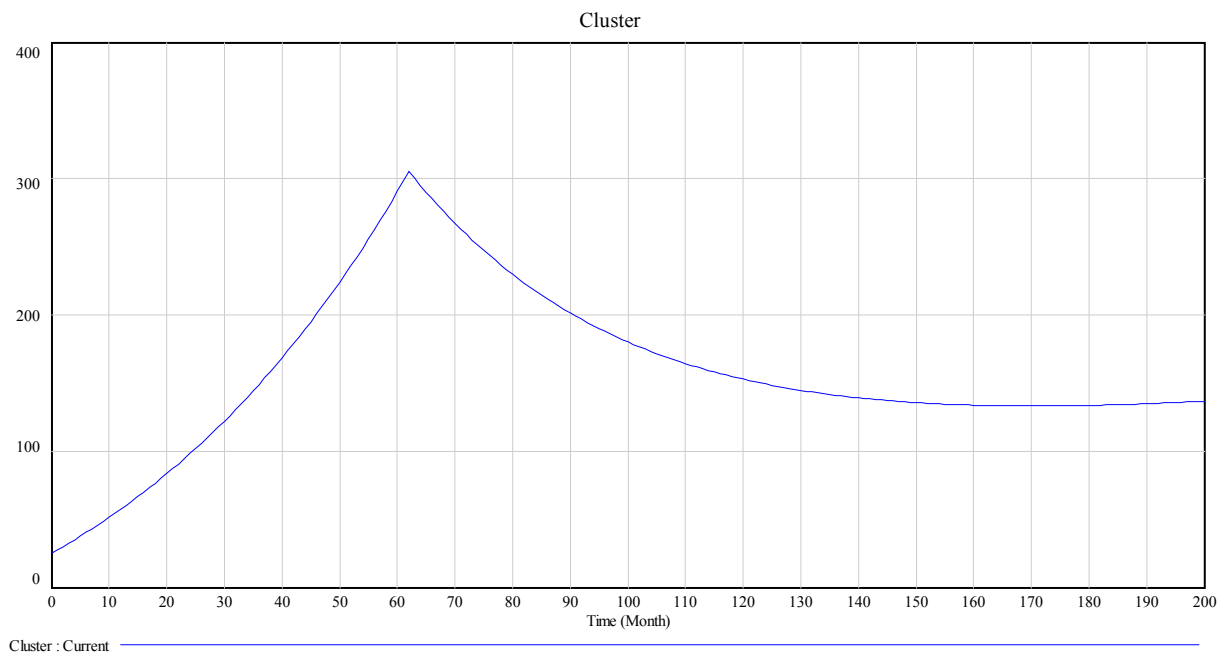


Figure 5: Cluster Evolution

Figure 6

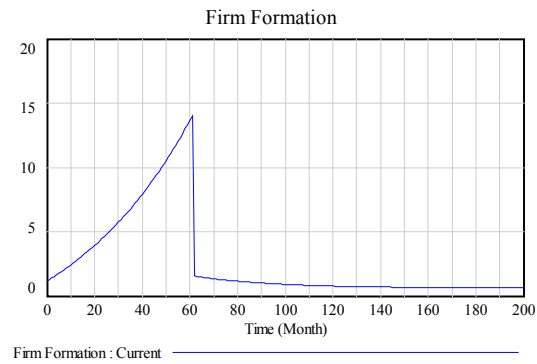


Figure 6: Firm formation rate

Figure 7

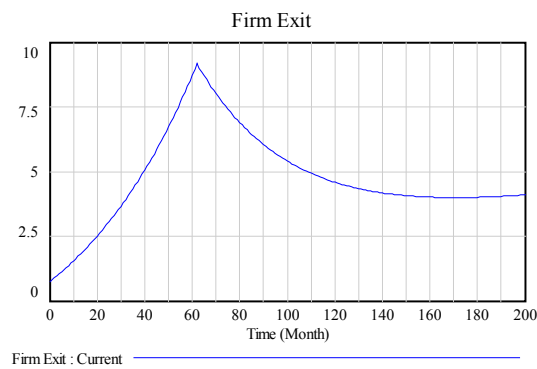


Figure 7: Firm Exit Rate

Figure 8

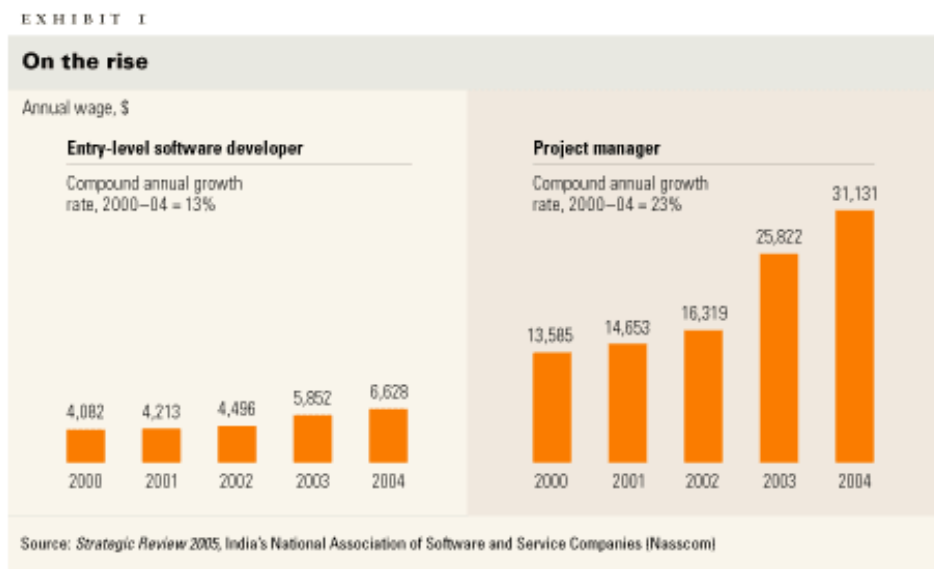


Figure 8: Wages increase in India