Industrial Network and Cluster: Restructuring Post-Pandemic Production Chains Based on Specialization and Division of Labor

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1. Introduction

Even after the 2020 pandemic subsides gradually, the world will be remarkably different with the system of global supply chain. The supply shock that begun in China in February of 2020 and the demand shock followed as the global economy shut down exposed the weaknesses and vulnerabilities in the production strategies and supply chains of firms. Those events, combined with the US-China trade war, have triggered a rise in economic nationalism. As a result, manufacturers worldwide will be under greater political and competitive pressures to increase their domestic production, grow employment in their home countries, reduce or even eliminate their dependence on sources perceived as risky, and rethink their usage of inventory from the global supply chains. All the concern has recalled our attention on the relevant issue of Industrial cluster and industrial network [16].

There are enormous studies have been conducted lately on the issues of Industrial cluster and industrial network, which reflect substantial concern over economic growth and development through global division of labor and specialization. Among them, Michael Porter [25, 26, 27, 28, 29, 30, 31, 32, 33] has discussed the "Industrial cluster" on the foundations of market economies which contains interrelated and dynamic mixtures of cooperative arrangements and competitive relationships. This research stream can be traced back and significantly influenced by Alfred Marshall's notions of "industrial districts" and "industrial atmospheres" [17,18], and also Piore and Sabel's term of "flexible specialization" [24]. Porter defines a cluster as a geographic concentration ("geographical proximity") of competing and cooperating companies, suppliers, service providers, and associated institutions, which is resulted from the relationships among factor conditions, demand conditions, related and supporting industries, corporate strategy, and structure and rivalry [27]. Moreover, Industrial clusters have been recently also studied as groupings of interrelated firms that innovate and generate economic growth, such as "collective efficiency" [34], the function and effect of knowledge externalities and spill-overs [3, 5, 7, 8], and the dynamic nature of interactive learning necessary for innovation [2]. Furthermore, Chandler argues that historically, economies of scale and scope have been achieved mainly by large private and public enterprises [6]. Similarly, Lazonick [15] and Florida and Kenny [9] also point out that large and high-end corporations a.re at the Heart of the innovation process and growth since they have, unlike small firms, the ability to combine technology, investment, clearly defined organizational structures, and the adoption of labor practices of flexible specialization, "just-in-time" production, and outsourcing; and multi-skilled and multi-tasked employees. Regarding the determinants of cluster, Nelson and Winter [20] and Nelson and Sampat [19] point out that location choice by firms is driven by transportation cost minimization and optimal combination of key location-specific inputs for an optimal level of production in order to maximize profit, and how institutional arrangement affects economic performance. The institutions are as standard "social technologies", and economic growth results from the co-evolution of physical and social technologies. According to Storper [36], firms in clusters or industrial districts are aimed at securing competitive advantage. In general, firms in clusters can take advantage of positive externalities and also force them to compete more fiercely with the firms within other clusters which will provide the incentive for the clustered firms to innovate [25]. Hence, cluster can be regarded as increasing various arrangements of networked firms, it can be considered as a broader scale as a foundation for economic growth, specifically at the level of the regional economy where promotion of entrepreneurial networks and clusters can occur [4, 14, 34, 38].

Regarding Industrial Network, the literature on networks has historical roots in both the theory of the firm and the literature on "growth poles". In particular, the latter recognises the leading firms' role and potential for positive spill-overs for a number of non-geographically concentrated production and commercial partners, through a "process of polarisation" or "propulsive development" [23]. In Perroux's original formulation, a growth pole referred to the linkages between firms and industries. "Propulsive firms" are those firms that are large relative to other firms and generate induced growth through inter-industry linkages as the industry expands its output [23]. This theory has significant impact in the promotion of "linkage studies" that, rather than being related to the idea of "geographical proximity" [29], it is more valid to develop and discuss the importance of linkages within trans-local firms, subsectors, commodity chains, as well as global supply chains [21]. All these arguments stress the importance of networks and linkages within wider spaces as a way to benefit from abilities and advantages that cannot be reaped in local economies alone. Besides, there are different meanings over networks depending on other theoretical approach adopted, such as theories of transactions costs, resource dependency, strategic management, and social network theory. There are basically three sets of concepts, based on strategy, network management, and social dimensions [39]. Harrison et al. [13] have seen technological learning as one of the dynamic agglomeration outcomes to be derived from combining geographical closeness and formal transactions based or informal relationships. In a context where the agglomeration of firms and institutions is relevant to enhance local competitiveness and make relational activities easier, the explicit interactive dimension of networking provides an indication of the relational thickness of the system as well as its openness with respect to linkages across different localities [1,11, 12]. As for Eisingerich, Andreas, Bell, and Tracey [9], there is a social network to develop regional cluster performance. High performing clusters are underpinned by network strength and network openness, but that the effects of these on the performance of a cluster as a whole are moderated by environmental uncertainty. The networks are instruments that may help firms to voluntarily expand their own competences by means of complementary partners beyond limitations of their own organisation and of the localities where they are settled. In this context, the process of "learning" offers a dynamic perspective on the nature of both networking and clustering [9]. Hence, following the competence view, networking can be beneficial because it may stimulate communication and convey new stimuli towards firms, thus enhancing learning opportunities that may lead to technological upgrading and improved competitiveness.

Although the notions of Industrial cluster and industrial network have been widely applied, they still largely remain fuzzy as a concept especially when we consider their own interrelated relationships and their relationships with the factors and variables from the whole economy, such as the institutional arrangements, trading efficiency, the level of specialization and agglomeration, as well as their dynamic evolutionary. The current literatures have addressed many important aspects of cluster and network, yet there is still short of robust frameworks to combine and explore them together under one competitive market. From these perspectives, further studies on overlapping meaning of Industrial clusters and networks need be conducted. In this paper, it will regard Industrial clusters and networks as two forms of production organisation, and they may be complementary with each other. This paper introduces a theoretically driven framework to provide structure and process related measures that can be used to explain how cluster and network actually operate and interrelate within an economy. The objective of this paper is to bring together the inter-individual strategic decision making and the network of division of labor in order to explore the conditions underlying the development of different types and level of Industrial Network, institutional efficiency of mutual trust, as well as geographically and non-geographically clustered. In particular, this paper will examine the relationship among institutional arrangement, fixed learning and entry cost, transaction conditions, and the cluster governance structure and process at the corporate level, the cluster level and/or the economy level.

2. A Model and Framework with Industrial cluster and Industrial Network of Division of Labor

2.1 The basic model

Following Yang [40], let's consider an economy with a continuum of consumer-producers of mass M. This assumption implies that population size is very large. It avoids an integer problem of the numbers of different specialists, which may lead to non-existence of equilibrium with the division of labor [37]. Each consumer-producer has identical, non-satiated, continuous, and rational preference represented by the following utility function:

(1a) $u = f(x^c, y^c)$,

where $x^c \equiv (x + k_x \cdot x^d)$ and $y^c \equiv (y + k_y \cdot y^d)$ are the amounts of the two final goods that are consumed, x and y are the amounts of the two goods that are self-provided, x^d and y^d are the amounts of the two goods that are purchased from the market, and $k_i \in (0,1)$ and $i = x, y$ or z. Fraction 1-k_i of a good sold disappears in transit due to an iceberg transaction cost, or k_i is a trading efficiency coefficient, which represents the conditions governing transactions. Regarding the effect of geographic concentration or Porter's "geographical proximity" [27], we further assume that $k_i = (1 - t_i) \cdot K_i$, and here t_i is the coefficient of relative geographic distance, and K_i relates to the general trading conditions and the institutional environment that affect trading efficiency. $f(.)$ is continuously increasing and quasi-concave. For simplicity without losing the generality, it is assumed that $f(.) = (x^c) \cdot (y^c)$.

Each consumer-producer's production functions are:

(1b) $x^p = x + x^s = max\{l_x - F,\ (z + k_z \cdot z^d)^\alpha \cdot (l_x - F),\ (z + k_z \cdot z^d)^\beta \cdot (l_x - F)\}$,

and $k_i = (1 - t_i) \cdot K_i$, and $i = x, y$ or z .

$y^p = y + y^s = l_y - b$ and $b \in (0, 1)$,

$z^p = z + z^s = l_z - b$ and $b \in (0, 1)$, where x^p and y^p are the amounts of the two final goods produced, z^p is the amount of the intermediate good produced, z^d is the amount of intermediate good z purchased from the market, x^s , y^s and z^s are the amounts of the goods sold. F is the fixed learning and entry cost in producing good x; and b is the fixed learning and entry cost in producing good y and z. F is the parameter representing the elasticity of output of good x with respect to input level of intermediate good z. Moreover, parameter α is the efficiency coefficient and general effect of roundabout production with intermediate goods, which will indicate one feature of economies of specialization and $\alpha \geq 1$ [40]. Besides, β is employed to indicate the degree and level of Industrial cluster, which means the efficiency coefficient of Industrial cluster, and it can be defined as $\beta = \alpha + e - \theta$. Here, θ represents the level of coordination cost, management cost and exogenous transaction costs of Industrial cluster, and $\theta \in (0, 1)$; and e is the institutional efficiency of mutual trust coefficient to describe external economic and technology systems for specialization and industrial agglomeration, and $e \in (0, 1)$. With the concern of the economies of agglomeration and the economies of specialization and division of labor, which are the major features of Industrial cluster, under certain conditions we can expect $\beta \geq 1$, which means there will be increasing returns in producing the final good x with cluster pattern. However, there will also involve all sorts of internal coordination cost, management cost and endogenous and exogenous transaction costs for manufacturing product x with cluster pattern. If without cluster, the firms will also encounter exogenous and endogenous transaction costs, such as transportation cost, measurement cost of quantity and quality of products, information searching and matching cost, anticipated moral hazard, knowledge block and many marketing related expenses, etc.. Hence, there is a trade-off here for engaged firms to decide whether to organise an Industrial cluster or just through the normal market trades, which will be analysed later in this paper.

The endowment constraint for each individual endowed with one unit of working time is given as follows:

(1c) $l_x + l_y + l_z = 1$,

where l_i is the amount of labor allocated to the production of good i. This system of production implies that each individual's labor productivity increases as she narrows down her range of production activities. As shown by Yang [40], the aggregate production schedule for three individuals discontinuously jumps from a low profile to a high profile as each person jumps from producing three goods to a production pattern in which at least one person produces only one good (specialization). The difference between the two aggregate production profiles is considered as positive network effects of division of labor on aggregate productivity. This network effect implies that each person's decision of her level of specialization, or gains from specialization, depends on the number of participants in a large network of division of labor, while this number is determined by all individuals' decisions in choosing their levels of specialization (so-called the Young theorem) [43]. Since economies of specialization is individual specific (learning by doing must be achieved through individual specific practice and cannot be transferred between individuals), labor endowment constraint is specified for each individual, so that increasing returns are localized.

The budget constraint for an individual is,

(1d) $p_x(x^s - x^d) + p_y(y^s - y^d) + p_z(z^s - z^d) = 0$.

Due to the continuum number of individuals and the assumption of localized increasing returns in this large economy, a Walrasian regime prevails in this model. The specification of the model generates trade-offs between economies of division of labor and transaction costs. The decision problem for an individual involves deciding on what and how much to produce for self-consumption, to sell and to buy from the market. In other words, the individual chooses *9* variables, such as $x, x^s, x^d, y, y^s, y^d, z, z^s, z^d$,, and there will be 2^9 amount of possible corner and interior solutions.

In order to narrow down the list of the candidates, Yang and Ng［42,43］used the Kuhn-Tucker conditions to establish the following lemma.

Lemma 1: Each individual sells at most one good, does not buy and sell the same good, nor buys and self-provides the same good at the same time.

We define a *configuration* as a combination of zero and positive variables which are compatible with Lemma 1. There are 14 configurations from which the individuals can choose. A combination of all individual's configurations constitutes a *market structure*, or *structure* for short. There will be totally 7 market structures compatible with Lemma 1. (See Figure 1)

2.2 Configurations and Economic Structures

Let's firstly examine all possible structures that might occur in equilibrium.

I. Autarky Structures: Structure A and Structure B

(1) Structure A (Autarky without Intermediate Good z) consists of all individuals choosing configuration A (self-sufficiency), where an individual produces all the two final goods for self-consumption and without any intermediate good z.

(2) Structure B (Autarky with Intermediate Good z) consists of all individuals choosing configuration B (self-sufficiency), where an individual produces all the two final goods for self-consumption and with intermediate good z for producing good x.

II. Structures with Partial Division of Labor: P_A , P_B and P_C

(1) Structure P_A is a partial division of labor structure which contains configurations (xy/z) and (zy/x).

(2) Structure P_B is a partial division of labor structure which contains configurations (xz/y) and (y/x).

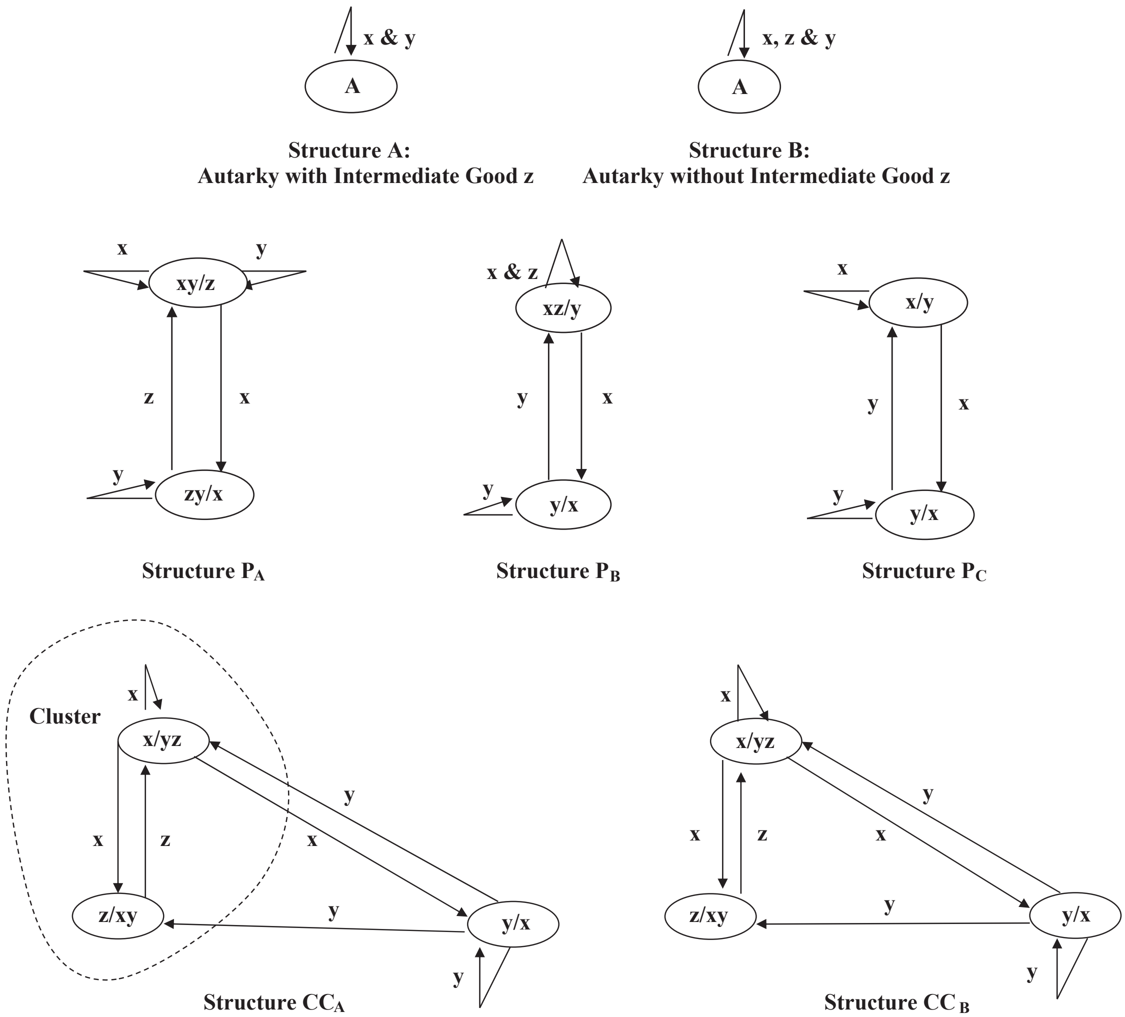
(3) Structure P_C is a partial division of labor structure which contains configurations (x/y) and (y/x).

III. Complete Division of Labor: Structure CC_A and Structure CC_B

(1) Structure CC_A is the complete division of labor with Industrial cluster which contains configurations (x/yz), (z/xy) and (y/x).

(2) Structure CC_B is the complete division of labor without Industrial cluster which contains configurations (x/yz), (z/xy) and (y/x). Note that the definitions and contents of their configurations are as same as Structure CC_A, yet it does not apply the Industrial cluster patter in the manufacture of good x. The rough explanation for this

Figure 1.　Configurations and Economic Structures



difference is based on the trade-off between different fixed learning and entry costs, the institutional efficiency of mutual trust coefficients of different economic and technology systems, the transaction costs and the level of coordination and management costs of Industrial cluster. The solid and explicit analysis will be addressed below.

According to Sun, Yang and Zhou [37, 40, 41], and Yao and Li [44], a general equilibrium is defined as a set of relative prices of goods and all individuals' labor allocations and trade plans, such that, (1) Each individual maximizes her utility, i.e., the consumption bundle generated by her labor allocation and trade plan maximizes her utility function for given prices; (2) All markets clear. More specific, Yang [40] has addressed the following theorem:

Theorem 1: For an economy with m goods and a continuum of ex ante identical consumer-producers with rational and convex preferences, and production functions displaying economies of specialization, and individual specific limited labor, the Walrasian general equilibrium exists and it is the Pareto optimum corner equilibrium.

Since the optimum decision is always a corner solution and the interior solution is never optimal according to Lemma 1, we cannot use standard marginal analysis to solve for a general equilibrium. We adopt a three-step approach to solve the general equilibrium. The first step is to narrow down the set of candidates for the optimum decision and to identify configurations that have to be considered. We can identify structures from compatible combinations of configurations, which we have done above. In the second step, each individual's utility maximization decision is solved for a given structure. The utility equalization condition between individuals choosing different configurations and the market clearing conditions are used to solve for the relative price of traded goods and numbers (measure) of individuals choosing different configurations. The relative price and numbers, and associated resource allocation are referred to as corner equilibrium for this structure. General equilibrium occurs in a structure where, given corner equilibrium relative prices in the structure, no individuals have an incentive to deviate from their chosen configurations in this structure. In the third step, we can substitute the corner equilibrium relative prices into the utility function for each constituent configuration in the given structure to compare the utility between this configuration and any alternative configurations. This comparison is called a total cost-benefit analysis. The total cost-benefit analysis yields the conditions under which the utility in each constituent configuration of this structure is not smaller than any alternative configuration. With the existence theorem of general equilibrium proved by Sun, Yang and Zhou [37], we can completely partition the parameter space into subspaces, within each of which the corner equilibrium in a structure is a general equilibrium. As parameter values shift between the subspaces, the general equilibrium will discontinuously jump between structures. The discontinuous jumps of structure and all endogenous variables are called infra-marginal comparative statics of general equilibrium, and the three steps constitute an Infra-marginal analysis.

Following this procedure, we can solve for corner equilibria in all structures. The solutions of corner equilibria in 7 structures, the relative prices and relative number of different specialists are summarized in Table 1.

3. General Equilibrium and Its infra-marginal Comparative Statics

Through infra-marginal analysis. it will partition the parameter space into subspaces within each of which a particular structure occurs in equilibrium. With the Theorem 1, we can then compare corner equilibrium per capita real incomes across all structures, and the comparison partitions the seven-dimension ($K, t, \alpha, b, F, e, \theta$) parameter space into several subspaces, within each of which one corner equilibrium is the general equilibrium. As parameter values shift between different subspaces, the general equilibrium discontinuously jumps between corner equilibria. This is referred to as infra-marginal comparative statics of general equilibrium.

In order to obtain analytical solution of the infra-marginal comparative statics for some specific ranges of parameter values, we conduct a close examination of per capita real incomes in different structures, which is given in Table 2.

Following Yang [40], it can be shown that a general equilibrium in this model is Pareto optimal. This first welfare theorem in this model with inter-individual networking decisions and endogenous network size of division

Table 1. Relative Prices, Per-Capita Real Income and Relative Number of Specialists in Different Structures

Structure	Relative Prices	Per-Capita Real Income	Relative Number of Specialists
A	N/A	$\frac{(1-b-F)^2}{4}$	N/A
B	N/A	$\alpha^\alpha \cdot \left(\frac{1-2b-F}{2+\alpha}\right)^{\alpha+2}$	N/A
P_A	$\frac{p_x}{p_z} = \frac{(1-2b)^{2-2\alpha}}{4^{1-\alpha} \cdot \alpha^\alpha \cdot [(1-t)\cdot K]^{2\alpha-1} \cdot (1-\alpha)^{2-2\alpha} \cdot (1-b-F)^{2-\alpha}}$	$\frac{(1-2b)^{2\alpha} \cdot \alpha^\alpha \cdot [(1-t)\cdot K]^{2\alpha} \cdot (1-\alpha)^{2-2\alpha} \cdot (1-b-F)^{2-\alpha}}{4^\alpha}$	$\frac{M_x}{M_z} = \frac{(1-2b)^{3-2\alpha} \cdot (2-\alpha)^{\frac{1}{1-\alpha}}}{2^{3-2\alpha} \cdot \alpha^{\frac{1+\alpha-\alpha^2}{1-\alpha}} \cdot [(1-t)\cdot K]^{\frac{4\alpha-2\alpha^2-1}{1-\alpha}} \cdot (1-b-F)^{\frac{3-3\alpha+\alpha^2}{1-\alpha}}}$
P_B	$\frac{p_x}{p_y} = \frac{(1-b)\cdot(1+\alpha)^{1+\alpha}}{\alpha^\alpha \cdot (1-b-F)^{1+\alpha}}$	$\frac{(1-b)\cdot \alpha^\alpha \cdot [(1-t)\cdot K] \cdot (1-b-F)^{1+\alpha}}{4\cdot(1+\alpha)^{1+\alpha}}$	$\frac{M_x}{M_y} = 1$
P_C	$\frac{p_x}{p_y} = \frac{1-b}{1-F}$	$\frac{(1-b)\cdot(1-F)\cdot[(1-t)\cdot K]}{4}$	$\frac{M_x}{M_y} = 1$
CC_A	$\frac{p_y}{p_z} = [(1-t)\cdot K]^{\frac{1}{2}}, \frac{p_x}{p_z} = P1$	u_{CCA}	$\frac{M_x}{M_z} = M1, \frac{M_y}{M_z} = M2$
CC_B	$\frac{p_y}{p_z} = [(1-t)\cdot K]^{\frac{1}{2}}$ $\frac{p_x}{p_z} = \frac{(1-F)\cdot(\alpha^{\frac{\alpha}{1-\alpha}} - \alpha^{\frac{1}{1-\alpha}})^{1-\alpha}}{(1-b)^{1-\alpha}\cdot[(1-t)\cdot K]^{\frac{1-\alpha}{2}}}$	$\frac{(1-b)^{3-\alpha}\cdot[(1-t)\cdot K]^{\frac{4-\alpha}{2}}}{4\cdot(1-F)\cdot(\alpha^{\frac{\alpha}{1-\alpha}} - \alpha^{\frac{1}{1-\alpha}})^{1-\alpha}}$	$\frac{M_x}{M_z} = \frac{(1-b)^2\cdot[(1-t)\cdot K]^{\frac{1}{2}}}{\alpha^{\frac{1}{1-\alpha}}\cdot(1-F)^{\frac{2}{1-\alpha}}\cdot(\alpha^{\frac{\alpha}{1-\alpha}} - \alpha^{\frac{1}{1-\alpha}})}$ $\frac{M_y}{M_z} = \frac{(1-b)^{2(1-\alpha)}\cdot[(1-t)\cdot K]^{\frac{3-2\alpha}{2}}\cdot(\alpha^{\frac{\alpha}{1-\alpha}} + \alpha^{\frac{1}{1-\alpha}})}{\alpha^{\frac{1}{1-\alpha}}\cdot(1-F)^2\cdot(\alpha^{\frac{\alpha}{1-\alpha}} - \alpha^{\frac{1}{1-\alpha}})^{2(1-\alpha)}}$

Here, $P1 = \frac{(1-F)\cdot[(\alpha+e-\theta)^{\frac{\alpha+e-\theta}{1-\alpha-e+\theta}} - (\alpha+e-\theta)^{\frac{1}{1-\alpha-e+\theta}}]^{1-\alpha-e+\theta}}{(1-b)^{1-\alpha-e+\theta}\cdot[(1-t)\cdot K]^{\frac{1-\alpha-e+\theta}{2}}}$, $u_{CCA} = \frac{(1-b)^{3-\alpha-e+\theta}\cdot[(1-t)\cdot K]^{\frac{4-\alpha-e+\theta}{2}}}{4\cdot(1-F)\cdot[(\alpha+e-\theta)^{\frac{\alpha+e-\theta}{1-\alpha-e+\theta}} - (\alpha+e-\theta)^{\frac{1}{1-\alpha-e+\theta}}]^{1-\alpha-e+\theta}}$,

$M1 = \frac{(1-b)^2\cdot[(1-t)\cdot K]^{\frac{1}{2}}}{(\alpha+e-\theta)^{\frac{1}{1-\alpha-e+\theta}}\cdot(1-F)^{\frac{2}{1-\alpha-e+\theta}}\cdot(\alpha^{\frac{\alpha+e-\theta}{1-\alpha-e+\theta}} - \alpha^{\frac{1}{1-\alpha-e+\theta}})}$, and $M2 = \frac{(1-b)^{2(1-\alpha-e+\theta)}\cdot[(1-t)\cdot K]^{\frac{3-2\alpha-2e+2\vartheta}{2}}\cdot[(\alpha+e-\theta)^{\frac{\alpha+e-\theta}{1-\alpha-e+\theta}} + (\alpha+e-\theta)^{\frac{1}{1-\alpha-e+\theta}}]}{(\alpha+e-\theta)^{\frac{1}{1-\alpha-e+\theta}}\cdot(1-F)^2\cdot[(\alpha+e-\theta)^{\frac{\alpha}{1-\alpha-e+\theta}} - (\alpha+e-\theta)^{\frac{1}{1-\alpha-e+\theta}}]^{2(1-\alpha-e+\theta)}}$.

Table 2. General Equilibrium and Its infra-marginal Comparative Statics (Example)

Trading efficiency of good k with the fixed value of θ	$K \rightarrow 0$			K are medium					K are large			
the efficiency coefficient of roundabout production α	α is small	α is large		K is relatively smaller given the value of α, β, F, t and b		K is relatively larger given the value of α, β, F, t and b			β is relatively smaller given the value of α; and the values of F and b are fixed		β is relatively larger given the value of α; and the values of F and b are fixed	
the fixed learning and entry cost F and b		b is relatively larger given the value of F	b is relatively smaller given the value of F	b is relatively larger given the value of F	b is relatively smaller given the value of F	b is relatively larger given the value of F		b is relatively smaller given the value of F				
the efficiency coefficient of Industrial cluster β												
the coefficient of geographic distance t						t is relatively smaller	t is relatively larger		t is relatively smaller	t is relatively larger	t is relatively smaller	t is relatively larger
Equilibrium structure	A	A	B	P_C	P_B	P_A	P_B	P_A	CC_A	CC_B	CC_B	CC_A

of labor implies that the market function is to coordinate inter-individual networking decisions and to fully utilize network effects of division of labor on aggregate productivity, network of transactions, and level off specialization and roundabout production.

In this model, the institutional efficiency of mutual trust related parameters (K, α, β), all play crucial roles in determining the per capita real income and the properties of the intermediate goods and Industrial cluster under the division of labor structure, and that is $\frac{du}{dK} > 0, \frac{du}{d\alpha} > 0$ and $\frac{du}{d\beta} > 0$. Industrial cluster and roundabout production both are related to the vertical division of labor between high-end and low-end producers in a long production chain, while the comparison between their institutional efficiency of mutual trust will be vital for the final decision in network structure of division of labor. Based on the above model, we can see that an economy with a higher institutional efficiency of mutual trust enables each individual to specialize in a narrow range of production and to enjoy economies of specialization. The benefits gained from increasing returns to specialization and the division of labor will outweigh the transaction costs of markets. Industrial cluster in a competitive market is an effective way to promote division of labor and productivity progress if the institutional efficiency of mutual trust of economic and technology systems are more competitive. We can summarize the above analysis into Proposition 1.

Proposition 1:

i) Absolute level of trading efficiency of goods determines the level of division of labor. As transaction efficiency is improved, the equilibrium level of division of labor increases, from autarky to complete division of labor; ii) Relative level of trading efficiency determines if the intermediate goods are self-supplied or through market transaction; iii) If the general effect of roundabout production is higher, then the roundabout production patter will be adopted; iv) The smaller fixed learning cost of intermediate good b, will increase the functions of the intermediate good, the level of production roundabout, the level of division of labor; v) If the efficiency coefficient of Industrial cluster overwhelms the general effect of roundabout production, the structure with Industrial cluster will prevail and thereby promote the division of labor and productivity progress based on inter-individual networking decisions, and it has no adverse effects on welfare and does not generate distortions in a competitive market.

Proposition 1 explicitly suggests a highly efficient transaction institution will sufficiently outweigh the transaction costs and provide each individual an incentive to specialize and to trade with each other by forming a network of division of labor.

Since there are more sophisticated interrelated effects among Industrial cluster, network of division of labor and production supply chain, thereby we need further expend our discussion on these interrelationships in the rest of this section.

Scenario 1. Fixed learning and entry costs of intermediate good z is smaller than final good x, that is $b < F$

From above analysis, we can easily derive that $\frac{du}{dF} < 0$ and $\frac{du}{db} < 0$ when they are under the structures of autarky and partial division of labor, which indicates the fixed learning and entry costs have negative effect for the development of network of division of labor and the level of specialization and roundabout production. However, when we derive them under the structures of complete division of labor, some interesting results emerging, $\frac{du_{CCA}}{dF} > 0$, $\frac{du_{CCA}}{db} < 0$ and $\frac{du_{CCB}}{dF} > 0$, $\frac{du_{CCB}}{db} < 0$, which implies that under the complete division of labor, the higher fixed learning and entry cost of final good will has positive effect in increasing the productivity as well as the per capita real income, while the one for intermediate good still has negative effect on productivity. In other words, if the entry barrier for final good x in term of fixed learning and entry costs goes up, which may cause by the technology barrier, patent, special know-how, R&D and innovation cost and systems, etc., it will generate higher producer and profit for the producers of final good x.

Besides, it has been addressed by many literature [22] that low-end and high-end sectors in one production supply chain usually have different fixed learning and entry costs, and high-end sectors have higher one with regard to their R&D inputs and varied costs for products development and quality control, etc.. If the degree and effect of Industrial cluster is stronger, i.e. the efficiency coefficient of Industrial cluster β is larger, even with $\boldsymbol{b} < \boldsymbol{F}$ we still can have $u_{CCA} > u_{CCB}$, which means the Industrial cluster is still prevailing as the optimal decision for the firm. Hence, in the term of production supply chain, the high-end firm, although they have larger fixed learning and entry costs, still can maintain their position in a competitive market if their efficiency coefficient of Industrial cluster is higher, which is determined by the trade-off between:1) the level of coordination cost, management cost and endogenous transaction costs; 2) the institutional efficiency of mutual trust coefficient to describe external economic and technology systems for specialization and industrial agglomeration, and that can be indicated by $\frac{du_{CCA}}{de} > 0$ and $\frac{du_{CCA}}{d\theta} < 0$. Therefore, to be the high-end or low-end of the production chain is not the personal choice anymore, it is substantially up to the institutional efficiency of mutual trust of economic and technology related systems, such as property protection systems for intellectual property and private property, the technology spill-overs effect mechanism, and information exchange and communication mechanism, etc., as well as the efficiency for coordinating and managing the Industrial cluster.

Since this model does not confine itself to one country only, it refers to one economy, and has no limit on the territory of One country. According to Porter [29], a cluster of independent and informally linked companies and institutions represents a robust organizational form that offers advantages in efficiency, effectiveness, and flexibility. Porter [27] addresses the local concentration processes that accelerate under the effect of globalisation. The competitive advantages of companies and industrial sectors participating in global competition are geographically concentrated, primarily due to agglomeration effects. He also mentions that it is not individual market players but rather regional clusters that participate in global competition. However, based on this model, under the new era of globalization and regionalization, we can also expend this economy among different countries with different production chains. From our analysis, the competition among different countries for high-end and low-end producers of one production chain is mainly based on the competition of the institutional efficiency of mutual trust among their economic and technology systems. The function of the institutional setting and efficiency of the economic and technology systems and the trading efficiency are crucially vital to determine the level of cluster, the network of division of labor, level of specialization and agglomeration, and consequent level of productivity and real income, rather than Porter's "geographical proximity" or geographic concentration [27], which can be approved by the results from Table 2, and also by the inequalities: $\frac{d(\frac{u_{CCA}}{u_{CCB}})}{dt} > 0$ when $\alpha \leq \beta$, and $\frac{d(\frac{u_{CCA}}{u_{CCB}})}{dt} < 0$ when $\alpha > \beta$. For particular, these inequalities and Table 2 indicate that even the geographic distance is larger, if the efficiency coefficient of Industrial cluster overwhelms the negative effect of geographic distance and the effect of roundabout production, Industrial cluster is still the optimal decision and an effective way to promote division of labor and productivity progress. In other words, if the institutional arrangements and settings are not efficient enough, even the geographic distance is sufficiently short, people will still choice the regular trading and roundabout production, instead of Industrial cluster. Hence, this model proves and implies that the Industrial cluster can be organized geographically or/and non-geographically.

Scenario 2. If high-end production is more profitable, then why the low-end firms or intermediate goods suppliers cannot move to high-end of the production supply chain?

Taking structure CC_A and CC_B into consideration, we can first derive the following relationships: $\frac{d(\frac{M_x}{M_z})_{CCA}}{dF} < 0$ and $\frac{d(\frac{M_x}{M_z})_{CCB}}{dF} < 0$, $\frac{d(\frac{M_x}{M_z})_{CCA}}{db} < 0$ and $\frac{d(\frac{M_x}{M_z})_{CCB}}{db} < 0$. The first group of inequalities implies if the high-end firm having a higher fixed learning and entry costs or entry barrier, the relative number of high-end firms will decrease which means when the entry barrier of high-end firms going up, it will be more difficult to become a high-end firm, and its relative number will go down. The second group of inequalities simply indicate that if the fixed learning and entry costs of intermediate goods going up, then the traction volume of them will decrease, and the incentives for purchasing intermediate goods from market will shrink. Consequently, the relative number of high-end firms which depending on them will also go down.

Scenario 3. The relative number of specialists with respect to the institutional efficiency of mutual trust under complete division of labor

Regarding structures CC_A and CC_B, we can first derive the following relationships: $\frac{d(\frac{M_x}{M_z})_{CCB}}{d\alpha} > 0$ and $\frac{d(\frac{M_x}{M_z})_{CCA}}{d\beta} > 0$. These two inequalities indicate that to become the high-end producer is depending on its institutional efficiency of mutual trust of economic and technology systems. The higher institutional efficiency of mutual trust will generate more high-end firms in a production chain. Therefore, the institutional efficiency of mutual trust is most crucial factor in determining the competition among different countries for the high-end and low-end production.

Scenario 4. The Hub of Network of Division of Labor

Considering structures CC_A and CC_B, we can derive the following inequalities: $\frac{d(\frac{M_z}{M_x})_{CCA}}{dF} > 0$ and $\frac{d(\frac{M_z}{M_x})_{CCB}}{dF} > 0$, which means when the fixed learning and entry costs of high-end firms are higher, then the relative number of intermediate goods and parts suppliers will increase. Since the entry barrier for the production of intermediate goods and parts are relatively lower, it will be more easily to enter this area, and the competition and high substitution and replacement effect among them are more severe. The intermediate goods and parts suppliers are forced to closely follow and surround the final good producer to survive. In other words, the high-end firms can control the final goods market through their high fixed learning and entry costs, such as the brand image, special know-how, patent, and market network, R&D and innovation capability, and etc., and they will be more likely to be the hub of the network of division of labor and also can control the intermediate goods and parts suppliers through OEM (Original Equipment Manufacturing), subcontracting and other manners. On the contrary, the low-end firms have to encounter the serious substitution and replacement effect and competition among them, and also the challenges from the newcomers which consecutively entering these markets.

The above analysis of different scenario can generate the following proposition 2.

Proposition 2:

i) Under the structures of autarky and partial division of labor, which indicates the fixed learning and entry costs have negative effect for the development of network of division of labor and the level of specialization and roundabout production; ii) Under the complete division of labor, the higher fixed learning and entry cost of final good will has positive effect in increasing the productivity as well as the per capita real income, while the one for intermediate good still has negative effect on productivity; iii) If the high-end firm having a higher fixed learning and entry costs, the relative number of high-end firms will decrease which means when the fixed learning and entry costs of high-end firms going up, it will be more difficult to become a high-end firm; vi) The competition among different countries for high-end and low-end producers of one production chain is mainly based on the competition of the institutional efficiency of mutual trust among their economic and technology systems; v) The improvement in institutional efficiency of mutual trust leads to an expansion in the network of division of labor and an increase in the relative number of specialists in high-end production to that in a low-end production; vi) The high-end firms can control the final goods market through their high fixed learning and entry costs, and are more likely to be the hub of the network of division of labor; vii) Comparing with geographic distance, the institutional arrangement and setting are more vital for the emergency and evolution of Industrial cluster. Industrial cluster can be organized geographically or/and non-geographically.

The above Proposition 2 indicates that as the institutional efficiency of mutual trust develops, the function of intermediate goods will improve, the network of division of labor will expend and the economies of specialization and agglomeration will increase. Our analysis is consisting with some of the observations, such as Storper［36］. Besides, Porter［25］also mentions that the increased innovation by firms generates new niches and needs within and outside the cluster, leading to the emergence of new firms and thus the expansion of the cluster and the economy as a whole. The expansion and growth of the cluster can lead to a more cohesive set of activities by the firms and become manifest as integration. Expansion and growth may also be a foundation for moving upward on the global supply chain. Increased integration in the global market brings new pressures to local production systems in developing and developed countries. Mixed with market pressures are a number of governance-related issues that determine whether and how a local production system (cluster or industrial district) remains in or moves up a global supply chain. Their arguments can be explicitly demonstrated by this model, while there are further insights from the propositions which are not clearly addressed before, such as, under the complete division of labor, the higher fixed learning and entry cost of high-end producer will has positive effect in increasing the productivity and expend the network; if the high-end firm having a higher fixed learning and entry costs, it will be more difficult to become a high-end firm; it will not be the individual decision anymore to become high-end or low-end producer, rather it will substantially depend on the competition over institutional efficiency of mutual trust of economic and technology systems among different regions or countries; the improvement in institutional efficiency of mutual trust leads to an expansion in the network of division of labor and bring more producers into high-end production; the high-end firms have been chance to control the market through their high fixed learning and entry costs, and are more likely to be the hub of the network of division of labor. Comparing with geographic distance, the institutional arrangement and setting are more vital for the emergency and evolution of Industrial cluster, and Industrial cluster can be organized geographically or/and non-geographically.

Our forgoing propositions also indicate that, a variety of economic structures may emerge in concurrence with economic development. They also support Adam Smith's [35] argument that the division of labor leads to the invention and the utilization of roundabout productive machines. Furthermore, they illustrate Young's proposition [45] that the division of labor for an economy is characterized by three components: the level of individual's specialization, its diversity of process, the new utilization of a good, its roundabout production, and the emergence of the vertical division of labor. This model also opposites the traditional argument that the "geographical proximity" [29] is more crucial to determine Industrial cluster and economic growth or economic development, and we indicate the institutional setting of a particular economy are more valid for the emergency and evolution of Industrial cluster and network of division of labor.

4. Concluding Remarks

This paper develops a Walrasian general equilibrium model based on inter-individual networking decisions to investigate the role of Industrial cluster and network of division of labor in a competitive market. In this model there is no monopoly power, substitution among different specialists are allowed, therefore to be cluster hub does not need to be as a large corporation, which has been occurred and observed in recent decades [6, 10].

The function of the institutional setting and efficiency of the economic and technology systems, and the trading efficiency, are crucially vital to determine the level of cluster, the network of division of labor, level of specialization and agglomeration, and consequent level of productivity and real income, rather than Porter's "geographical proximity" or geographic concentration [27]. Industrial cluster in a competitive market is an effective way to promote division of labor and productivity progress if the institutional efficiency of mutual trust of economic and technology systems are more competitive, and it has no adverse effects on welfare and does not generate distortions in a competitive market. Hence, a competitive market will fully explore total positive network effects of division of labor on aggregate productivity.

Industrial cluster in a competitive market is efficient and it ensures the network effects of division of labor can be fully exploited when the institutional efficiency of mutual trust of Industrial cluster overwhelms the general effect of roundabout production, and Industrial cluster can promote aggregate productivity by enlarging the network effects of the division of labor against transaction costs. Hence, our attention should be placed on the improvement of institutional efficiency of mutual trust of economic and technology systems, promotion of innovation and R&D, and maintain the institutional setting for free entry and learning process. Some promising extension of this model are to allow more layers of roundabout production, to count more variety over the conditions of trading efficiency and geographic distance, and to expend to the dynamic process for the interrelationship among Industrial cluster, industrial network and institutional settings.

Especially after the 2020 pandemic, the world will be expected markedly different with the system of global supply chain. The institutional efficiency of mutual trust will become more vital and crucial to determine the global production network, particularly for the high-end production pattern.

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