LUND UNIVERSITY
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Master programme in Economic History

Product space, unrelated diversification, and economic development

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Abstract: Product Space methodology introduced in 2007 initiated a new perspective in diversification studies. It finds out stylized facts that generally developed countries mainly export core product (metal, machinery, chemicals), while developing countries mainly export periphery products (agriculture, primary goods). Besides, these two types of products have very low proximity. They do not share many common capabilities with each other. Core industries have merits in three aspects, 1) more capabilities embedded, 2) higher export value, and 3) more potential to diversify to others. Consequently, if developing countries are willing to enjoy the merits, they have to diversify from periphery products to core products, and the diversification process is naturally unrelated. Thus, here comes the research question which has been neglected by most diversification studies, that *how developing countries can diversify to unrelated core industries*. This paper does not intend to answer this big question. Instead, it uses South Korea, one of the most successful countries in economic growth and product diversification, to highlight some possible mechanisms for its intense diversifications through case studies. However, product space method is data-driven, so this paper also argues Evolutionary Economic Geography could complement it by providing micro foundations. This paper finds out firstly, Korea indeed experienced a sharp unrelated diversification, from periphery to core products. Secondly, by three case studies, this paper finds out, chaebol's interaction with supportive government, stepping-stone industries by import substitution, and public-private R&D cooperation all could explain Korea's strong unrelated diversifications. Meanwhile, three cases also indicate governmental involvement functioned delicately in special institutional arrangements. This paper supports government intervention to help create capabilities to facilitate unrelated diversifications, so developing countries can possibly reach core products and get developed. Finally, this paper also indicates further studies in unrelated diversification for developing countries as well as some challenges for EEG.

Key Words: Product space, diversification, unrelated variety, development, Evolutionary Economic Geography.

EKHM52
Master thesis, second year (15 credits ECTS)
June 2016
Supervisor: Lars Coenen, Fredric Bauer
Examiner: Karl-Johan Lundquist
Word Count: 14376

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Acronyms and Abbreviations

EEG	Evolutionary Economic Geography
ETRI	Electronics and Telecommunications Research Institute
HCI	Heavy and Chemicals Industries
ISI	Import substitution industrialization
OECD	Organization for Economic Co-operation and Development
RCA	Revealed Comparative Advantage

1. Introduction

The emergence of new products or new industries attracts more and more attentions, because it is essential for country or region's economic growth. Among diversification studies, recent developed methodology Product Space (Hidalgo el al, 2007) provides a unique perspective. It uses export data to measure the revealed comparative advantages of each county, and map the relatedness between different products. This method not only reveals the relationship between every product in the world, but also map different country's products portfolio. Product Space studies find out two clear stylized patterns. For products, it display some products are located isolated in the periphery, while some products are in the core regions and have close connections with many other products. For countries, developing countries mainly produce periphery products, and developed countries primarily manufacture core products, mainly are metal, machinery, chemicals three types of industries. This paper will specify three specialties of these core industries from product spaces methods, in order to highlight their merits for long-term economic growth. Given the importance of core industries and the inspiration from Evolutionary Economic Geography (EEG), this paper will present the research question which has been neglected by current diversification studies: *how developing countries can diversify from periphery industries to unrelated core industries*. This question is crucial for developing country, because most of them are positioned in periphery and in order to gain long run economic growth they anyway have to diversify to unrelated products. On another hand, product space is only a data-driven method, and lacks micro foundation, like firm's behavior. In order to thoroughly understand diversification process and generate policy implications, this paper also argues, EEG could complement product space. EEG has clear micro mechanism of diversifications, in terms of knowledge transfer, interactive learning and innovation, regional branching of new activities. We need to analyze from both macro product space and micro EEG to understand how developing country could diversity from its periphery to unrelated core industries. In terms of empiric studies, this paper does not intend to provide a solid answer to this question. Instead this article will use South Korea, the most successful country in both economic growth and product diversification, to provide inspirations for further studies. Specifically, Korea diversification patterns will be displayed in empirical parts, followed by case studies to illustrate some possible micro mechanisms for their unrelated diversification, and then discuss how these micro mechanism fit (or not) into EEG theories. This paper has three

contributions. Firstly, it compares product Space with EEG, and claims they could complement each other; secondly, it provides evidence that core industries (metal, machinery, and chemicals) are important from three aspects; lastly, it uses Korea case to imply possible micro mechanisms for unrelated diversification, and enlighten on some practical implications for developing countries to achieve diversification and economic growth.

Section two will firstly go through Product Space method and EEG, and discuss their similarities and differences, and illustrate their complementary relationship. Section three will introduce product space methodology in details, and variables we will use in empirical parts. Section four will review the former studies from product space, and highlight the importance to understand how developing countries can diversify to unrelated core industries. Section five empirical studies will be divided into two parts. First part will show core industries are important for long term economic growth from three aspects. Second part will discuss Korea's three cases to elaborate how Korea diversified to unrelated core industries, and also how these mechanisms fit into or challenge EEG framework. Section six will provide discussions regarding to the limitations of this thesis, possible policy implications as well as further studies. Section seven will be an overall conclusion for this thesis.

2. Product Space and Evolutionary Economic Geography

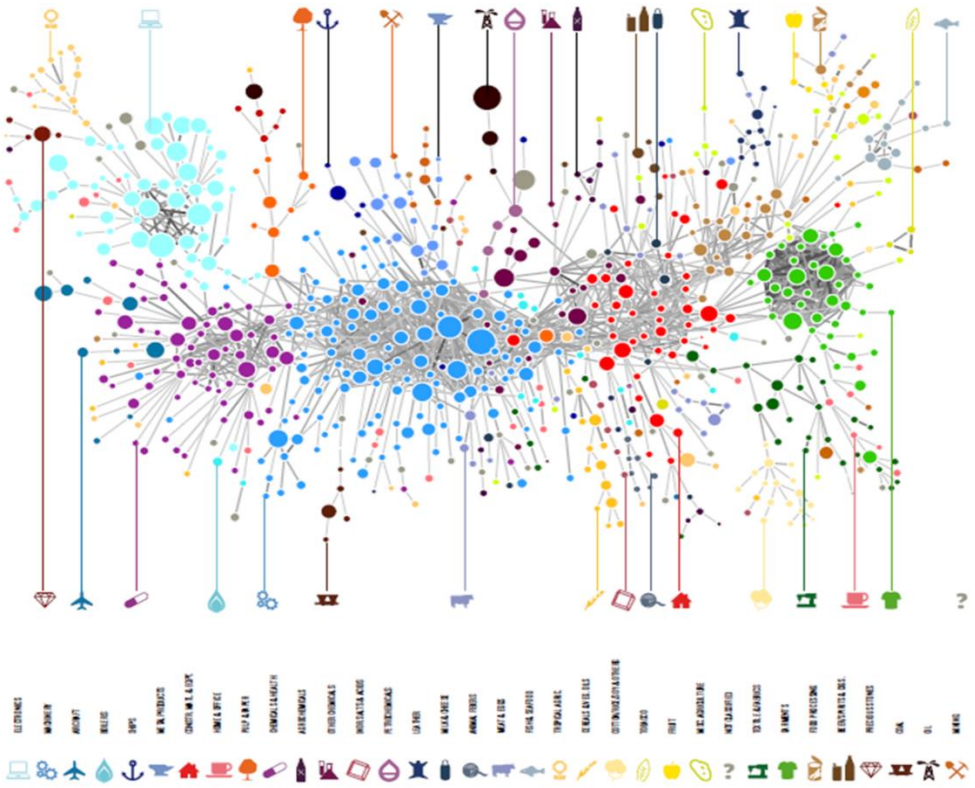
2.1 Product Space

Basically, product space provides a new methodology to measure the proximity or distance between different products from export data. The distance between two products is the probability of one country co-exporting two products at the same time with revealed comparative advantages (RCA). RCA is determined by whether this country's export ratio of this product is higher than world export ratio of this product. If yes, this country has RCA in this product. For example, we could find out proximity between fridge and microwave is very high from trade data. This means there is a very high possibility that countries which export fridge with RCA also export microwave with RCA, and vice versa. We could find out the proximity between fridge and insulin is rather small. This means there is a very little chance that countries export fridge with RCA also export insulin with RCA, and vice versa. These findings does not contradict our intuitiveness, because fridge and microwaves are both household applications and hold many similarities, while insulin belongs to pharmaceutical field, dramatically different from household applications. After calculating the proximity for each pair of products, Hidalgo el al (2007) further map the product space using network analysis. The product space map reveals many interesting patterns. For instance, some industries cluster in the middle core position, while some others are located in the periphery, and have low proximity and long distance with most other products (Figure 1).

Concept "capability" is crucial to explain the connections between countries and products. That is, why countries' production basket are so different to each other, and also why some products can only be produced by some countries but not others. Product space literature assumes different product requires different combinations of capabilities, and different country possesses different capabilities (Hidalgo el al, 2007, Hidalgo and Hausmann, 2009). For example, products which can be produced by a large number of countries only require basic capabilities. Complicated products which can only be produced by a small number of countries would need rare capabilities. Countries with a high degree of diversification (high number of export products with RCA) have more capabilities, and thus normally produce more complicated product. Countries with a low level of diversification have fewer capabilities, and hence produce more simple products. However, it should bear in mind capabilities' domain here is very broad,

and it could be anything which is required for producing goods, including infrastructure, general personal skills, knowledge, institutions, rules, and norms, etc. (Hausmann and Hidalgo, 2010:27).

Figure 1: Product Space of World



Source: Hausmann el al (2014)

Details about product space's calculation method will be introduced in section four.

Though the proximity measurement is totally data driven, Hausmann and Klinger (2007) introduced a straightforward model to interpret the different proximity between products. They developed the model of product-specific human capital, with heterogeneous degree of substitutability across products. That is to say, the proximity between different products could be explained by the substitution degree of product specific human capital. For example, microwave and fridge have high proximity because large amount of their product specific human capital overlap and can be substituted with each other. Besides, it also been used to understand diversification. The diversification process could be understood as cost-benefit analysis by deploying different extents of current human capital to another product (Hausmann and Klinger, 2007; Boschma & Capone, 2014a). Nevertheless, this understanding seems to

provide a micro understanding of diversification (redeploy human capital), but it is totally ex post and only provide a vivid way to understand product space, but not real micro foundations.

2.2 Evolutionary Economic Geography

Frenken and Boschma (2007) provide a theoretic framework for Evolutionary Economic Geography (EEG), which specifies "process of economic development as an evolutionary branching process of product innovations." This process put analyses of branching on firm level. It elaborates the process of how firms learn from knowledge spillovers, and further introduce new products. EEG perceives the uneven distribution of economic activity across space as outcomes of historical process. This is quite different from neoclassic understanding, which explains by equilibrium instead of historic path. Briefly, EEG treats economic growth as the process of firms introducing new products based on past experiences.

From the perspective of EEG, firms will depend on their organization routines in relevant productive and decision-making processes. Firm's organizational routines consist of large extent of experience and tacit knowledge. Routines are built on over time and path dependence, and also special to particular firms. These routines are the fundamental competitiveness of the firms, because routines provide firm a bunch of options for producing specific outputs, and they cannot be easily imitated or learnt by other firms. Simultaneously, market will serve as a selection mechanism upon different routines among firms, and lead to different growth rate for firms (Nelson and Winter, 1982). From this perspective, if firm could diversify to a new product, it needs to possess new routine. The new routine would be closely related to the old routine, because it is from recombining or modifying existing routines. One paradigm would be that firm diversifies to technological related new product.

Consequently, routine replication is the channel to new products. There are three mechanisms of routine replications. Firstly, setting up new division or subsidiaries within the firm; secondly, spin-off firm inherit part of routines from current firm; thirdly, routines replication is through labor mobility. In terms of special dimension, all three mechanisms can take place locally or over distance, but generally happen locally. Moreover, this framework also clarifies different mechanisms breed different extent of innovations. Incremental innovation would expect to might benefit more from existing routine, thus occurs more in new divisions of the same firm.

Radical innovations, by contrast, will rely more on different routines, and are fostered mainly from spinoff and labor mobility mechanisms. Correspondingly, radical innovations also have higher chance to emerge over distance than incremental innovations. (Frenken and Boschma, 2007)

To sum up, EEG provides a comprehensive micro foundation of economic geography to study industrial dynamics and urban growth. We will zoom into EEG's widely studied and core part of firm routines---knowledge maintained by firm, in order to get clear understandings how firms branch new products. Based on this big framework above, in the following content, we will follow the coherent logic to discuss: how proximity could facilitate interactive knowledge learning and innovation, and how interactive learning will possibly go to branching (Boschma, Frenken, 2009)

Within EEG framework, five proximities would facilitate firms' interactive learning and innovations (Boschma, 2007). They are cognitive, geographic, organizational, social, institutional proximity. They function in different way, but all reduces uncertainty and solves the problem of coordination. Geographic proximity is important in discussion, because geography can facilitate interactive learning by strengthening other proximity. For example, generally it would be easier for firms to learn from local than from distant regions. However, Boschma also clarify geography proximity is not necessary or sufficient; it needs to cooperate with other proximities, and could be substituted by others.

Among them, cognitive proximity provides the base for firms to learn and innovate, and an optimal distance can promote large degrees of knowledge spillovers and interindustry learning. Too little cognitive proximity will bring misunderstanding while too much would lack novelty. Cognitive and technological relatedness are not exactly the same. Cognitive is embedded in actor, while technological relatedness is embodied in production (Boschma & Frenken, 2011). However, these two are very similar in understanding branching. EEG articulates there are four mechanism of technically related: technology feedback from producer and user linkage; production-system interdependency; technological complementarity; and technical interdependencies originating from common technology. Besides, based on these technically relatedness or cognitive proximity, there are four knowledge transfer mechanisms. They are spinoff through entrepreneurship, firm internal diversification, labor mobility, and social networking. New activities branching occur through above knowledge transfer mechanisms. To

be specific, spinoff and firm diversification are the key symbols of regional branching, while labor mobility and network could facilitate knowledge diffusion, but may or may not engender branching. All these four are generally geographically bounded, but not necessary, as discussed about geographic proximity could be substitute by other proximity.

To summarize, EEG provides a clear reasoning line for regional branching. Five proximities could facilitate interactive learning, and interactive learning may initiate regional branching, and branching is realized through four types of knowledge transfer with technological relatedness or optimal cognitive proximity.

2.3 Relationship between product space and EEG

Product space does not have strong theories underlying the empirical findings. It uses the different degrees of substitution of product-specific human capital as main reason to understand different proximity between products. To be specific, why two products have high proximity (high possibility to co-export with RCA) is because large amounts of one product's specific human capital could substitute another's, thus these skills could be redeployed easily from one to another. However, there remains a big problem for thorough understanding. What are the redeployment mechanisms? It is very unclear. Thus, this paper will argue these two research strands (EEG and product space) could complement each other. EEG could provide micro mechanism for product space, and product space could reveal empirical finding to enlighten EEG theories. Their complementary are profoundly important. As will discuss in next section, right now all product space policy implications are based on empirical findings, if we cannot know the mechanism, how feasible the policy could help country, region, or firm really to diversify to new activities. For example, even though we know microwave and fridge have very high proximity, then we can only advise country now good at exporting microwave could also diversify to fridge. However, we still have no idea through which mechanisms how country or firm specialized in microwave can also produce and export fridge. Hence, it would be fruitful for policy if we also know the micro mechanisms.

Similarities

Product Space and Evolutionary Economic Geography have many similarities. Firstly, EEG views "process of economic development as an evolutionary branching process of product innovations." And each product innovation provides an opportunity of growth for existing firm or new firm (Frenken & Boschma 2007:645). Product Space view economic growth as country continuously accumulate new capabilities and combine old capabilities to operate new activities and product new products (Hidalgo el al, 2007, Hidalgo 2009, Hausmann & Klinger 2007). Therefore, both theories view continuous product innovation is the essence of economic development. Secondly, firm routines in EEG are very similar to capabilities in product space literature, "one can thus think of diversification as a branching process in which new routines associated with a product innovation are generated by recombining and modifying existing routines"(Frenken & Boschma 2007:637) At the same time, product space claims product requires different capabilities embedded in country, and new product needs new combinations of old capabilities or acquire new capabilities (Hausmann & Klinger 2007). Thirdly, product Space emphasizes countries' existing products matter for future. Because existing products manifest the underlying capabilities embedded in the country, and these capabilities will determine the future development. So there is path dependence, and countries tend to step into new activities which have high proximity with their existing products. Likewise, EEG also has an evolutionary dynamic process and path dependence on firm's routines. Fourthly, EEG's "related variety" concept is very similar to proximity in product space. The source of related variety in EEG's mainly refers to technological variety, while the source of proximity in product space is product-specific human capital. EEG's related diversification is based on technological relatedness, and diversifies to similar technology based product. This corroborates empirical finding from product space that most countries diversify to their nearby product.

Differences and complement

These two theories do have many similarities and connections as discussed above. Nonetheless, they are still quite different in other perspectives.

Firstly and foremost, product space is originally a method for relatedness measurement, then it comes up with human capital model to explain the empirical finding, but very weak and lack

micro mechanisms. Consequently, product space method is unclear about process. It is still unknown how country, as an aggregated entity, accumulates capabilities and diversifies to other products, while in EEG, how knowledge is created and transferred, and how firm absorbs knowledge and branches into new activities are rather clear. Therefore, it would be great to use EEG to complement product space, and help understand micro foundations. Luckily, there is a chance to connect these two, because product space lies in product, while product is naturally produced by firms. Moreover, product-specific knowledge is also obviously held in the firms, so they could connect through the channel of firms. Secondly, product space diversification is mainly discussed knowledge transfer from one product to another based on redeployment of product knowledge, while EEG is more progressive. It contains both knowledge transfer and knowledge creation, which is based on optimal cognitive proximity. Thus, product space actually could learn from EEG about knowledge creation, since it is very relevant to capabilities building in product space literature. Thirdly, EEG rests mainly in regional level, while product space is in country level. This difference could be a big problem, but not necessary. With Boschma's (2007) five proximities, we could know geographic proximity could be substituted by other proximities, so interaction learning and innovation not necessarily only happen in regional level. Besides, their difference actually could potentially assist each other. For example, if branching happens beyond internal region, regional branching mechanisms could be expanded to inter-regional level, as we will see in Korea case study. If the branching mainly happens in region, since nation is the aggregations of regions, these branching and path dependence could somehow disclose in national level as well, thus product space still could be a useful tool in understanding diversification. Fourthly, as discussed above, product space's "capability" concept is very fuzzy. Any factors involve with producing different goods can be "capabilities", including infrastructure, general personal skills, knowledge, institutions, rules, and norms, etc (Hausmann and Hidalgo, 2010:27) It is more difficult to capture "capabilities" since they rest an national level. By contrast, EEG's firms routines are well defined and much clearer, thus EEG provides a handle for policy to work on while product space does not. Last but not least, EEG's studies could be argued as Euro-centric, and discuss and test in the context of developed countries, thus its findings might be limited, and there could be a big blind spot EEG cannot capture. On the contrary, product space applies to all countries, and finds out the vast difference between developing and developed countries in manufacturing ability. Our research question is actually from the blind spot, and will be emphasized in next section.

To sum up, product space and evolutionary economic geography could complement each other. Product space provides the macro diversified pattern, and EEG could specify the micro foundation and mechanisms. Only by combining these two, we could know thoroughly the diversification process at both national level and firm level. Then we could generate practical policy implication, such as how can country exploit its current capabilities to diversify to nearby products, and how country can gain new capabilities to step in unrelated products. The comparison between EEG and product space is summarized in Table 1.

Table 1: Comparisons: Evolutionary Economic Geography and Product Space

	Evolutionary Economic Geography	Product Space
Attribute	Theory	Data driven Methodology
Source of Growth	New products	New products
Evolutionary	Yes	Yes
Spatial level	Regional	National
Relatedness	Technological relatedness (cognitive proximity)	Product specific human capital
Source of diversification	Knowledge transfer; Knowledge creation by interactive learning	Knowledge transfer
Abilities of diversification	Firm routines	Country capabilities
Study object	Firm behavior	Product
Micro Mechanisms	Technological related mechanisms, Knowledge transfer mechanisms, Proximity for knowledge learning	No micro diversify mechanisms
Applications	Developed countries	All countries
Purpose	Economic growth, resilience, new path creation, regional innovations.	Economic growth, capabilities accumulations.

Source: author's summary.

3. Literature review

This part will review current findings from product spaces, and highlight three stylized facts. And then we will use these facts to imply the dismal future for developing countries, and thus come up with our research question. Afterwards, we will discuss why this question is important along with how does EEG perceives this question, concluded by EEG's blind point which this paper tries to address.

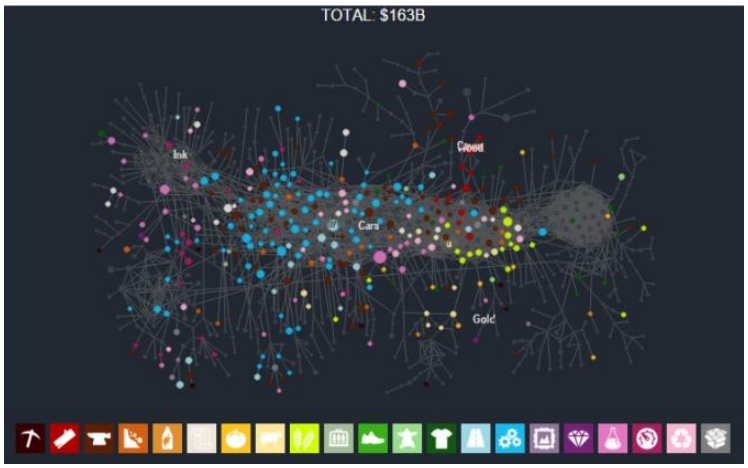
There are three stylized facts about product space. 1) Product space is heterogeneous with clear core-periphery structure. 2) Industries are different in terms of their position in product space. 3) Developed and developing countries are positioned in different areas and different industries. Firstly, conventional economic theories, especially neoclassic theories, perceive product space as homogeneous and continuous. This assumption means that every product is surrounded by countless products with varying distance, and country can climb up the ladder of comparative advantage through these products (Romer, 1988, Aghion-Howitt, 1992). However, product space finding harshly reject neoclassic theories. As showed in *figure 1* in last section, empirical studies find out product space is far from homogenous, but appears as a core-periphery structure. In the core regions there is high density of products, and distance between products is short (proximity between them is high). That is to say, it is very easy to find out two products have strong relatedness. We would expect that it is not difficult to export a new product from an existing close product, since they are very close. By contrast, the periphery parts contain very few products, and the distance is long to most other products in the space. This indicates their relatedness to most others is very weak, and to diversify to other products from periphery could be very arduous.

Secondly, besides core periphery structure, it is also interesting to know core region is prevalently occupied by three industries, namely metal, machinery, and chemicals by Leamer (1984) categories[1]. Periphery is formed by the rest of products, including primary sectors, agriculture products, and labor-intensive industries. These industries have been explicitly identified in former studies (Hidalgo et al, 2007, Felipe et al, 2013b, Felipe et al 2012).

[1] Refer to Appendix Table 1

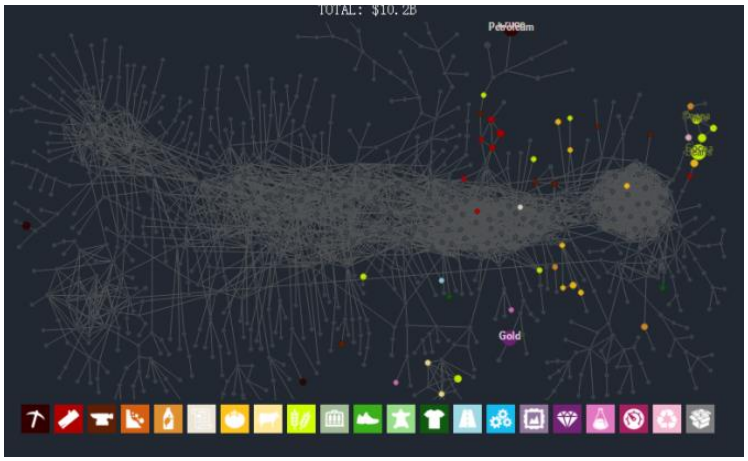
Thirdly, besides different products are positioned in different places in core-periphery structure, countries also share similar rule. In terms of countries, developed countries occupy the core regions, and have a large number of products. Developing countries, by contrast, have much smaller number of products, and are positioned in the periphery products regions. *Figure 2* and *Figure 3* use one developed (Austria) and one developing country (Ghana) as paradigm. There are only very few exceptions, like rich oil countries are positioned in the periphery, and few emerging countries, including China, Korea, India have similar positions like developed countries in core regions (Felipe et al, 2013a, 2013b, Jankowska el al, 2012).

Figure 2: product space of Austria in 2014



Source: Simoes (2010)

Figure 3: product space of Ghana in 2014



Source: Simoes (2010)

To sum up the above three stylized facts, we could find out dichotomy pattern in the world. Developing countries mainly produce primary goods, agriculture products, and labor-intensive products in the periphery position; while developed countries mainly produce metal, machinery, and chemicals products in the core position. It would be natural to imagine developing country is harder to diversify, because they need to cover a longer distance to most other products, and highly possible get trapped in their existing periphery positions. Product space recent studies do support this speculation.

There is strong path dependence for country to diversify to new products. Countries tend to develop new product close to old products. In other words, emergence of new industries does not surge randomly, but usually has high proximity with exiting industries (Hausmann & Klinger, 2007). However, it should be aware that developing countries are positioned in the periphery, where there are not many products nearby for them to follow path dependence. Besides, country with denser existing product profile tends to be easier in diversification (Hidalgo et al, 2007:485). In another word, since most developed countries have denser product profile in the core region, they are likely to diversify to more products and to use a shorter time, comparing to developing countries in the loose periphery. From the perspective of capabilities, Hausmann and Hidalgo (2010) finds out the return to accumulating of new capabilities is strongly associated with exiting capabilities. Accordingly, it is not easy for poor countries to accumulate new capabilities. On the contrary, since rich countries have already maintained many capabilities, they could acquire new capabilities easier, and then diversify to more industries. Lastly, Hidalgo et al(2007:486) have done three simulations to show endeavors needed for developing countries. They put high-income countries' product positions as final target, and simulate how developing countries can catch up. It finds out they must have extremely strong ability, and every time cross a long distance, then they could reach the positions that high-income counterparts hold.

All above empirical findings lead to the dismal conclusion for developing countries. If we perceive economic growth as accumulating more capabilities and introducing new products, then most high income countries have natural advantage. They could diversify and grow much easier than poor countries. This perspective supports the view of endogenous growth model: the world is experiencing divergence instead of convergence. Thus, unlike most product space

studies (Hidalgo, 2011; Hidalgo & Hausmann, 2009; Boschma & Capone 2014a) stop at suggesting country should follow product path dependence, to explore "nearby" product, this paper move one step further, and come up with the following research question:

How can developing countries diversify to unrelated core industries?

It is noteworthy that this paper does not decline most studies' path dependence suggestions. This paper also agrees that to follow path dependence is the natural way to get more diversification and economic growth. However, this paper claims this suggestion is not enough, and the long-distance unrelated diversification is more essential for developing countries, but has been neglected. For instance, it is very reasonable and feasible for Hidalgo (2011) to advise Eastern African countries to diversify to nearby agriculture products. However, to a certain point, when these easy short-distance diversifications have been achieved, he has to answer the question how to diversify to core industries in order to further catch up. This kind of diversification has to cover a long distance, because there is inherently big gap between core and periphery products from product structure. This is also why these essential diversifications in our research question are naturally unrelated to old periphery industries.

Why diversify to core industries are important? Core industries (metal, machinery, and chemicals) are vital for several reasons. Their importance lies in three aspects, that is 1) core industries require more capabilities[2] 2) core industries have a large value[3] in export 3) acquiring core industries will have better diversification potential[4]. These three aspects will be thoroughly examined in empirical part. First aspect indicates that core products are prevalently the most complicated products, which contain larger number of capabilities and more sophisticated capabilities. Thus, if a country has ability to produce some core products, it obviously possesses these sophisticated capabilities, so it would be easier for this country to produce other products by deploying these capabilities (Hausmann & Hidalgo, 2010). Second aspect shows that if country can manage to produce core products, this country can reap the high value from export, which is directly relevant to economic growth. Lastly, among all industries, core industries have the highest potential to diversify to other products, based on their high proximity to most products. This aspect is in line with our crude observations from *figure 1*. Consequently, the

[2] By variable PCI, defined in methodology
[3] By variable PRODY, defined in methodology
[4] By variable PATH, defined in methodology

above three aspects are the underlying reasons why countries occupying in core industries are mainly developed countries. Moreover, it again convinces us that to study *how developing countries can diversify to unrelated core industries* is profoundly important.

Though there are no product space studies directly relevant to unrelated core industries, Felipe el al (2013a, 2013b) indeed touched this question by discussing diversification patterns of China and India. Felipe finds out unlike many other developing countries, China and India are extraordinary exceptions. Both countries diversified to many different industries over last forty years, and also possess a broad representation in core industries. At the same time, two papers reviewed the major industrial policy of two countries, and attempted to understand their great performance in diversifications. To be specific, China firstly followed import substitution, and later changed to export orientation, but at the same time protected internal strategic industries, mainly core industries. China built up capabilities domestically for these core industries and simultaneously make use of its labor-intensive industries. Indian economic performance was not as good as China, because India excessively implemented policy targeting to core industries. With many inefficiency and distortions, according to Felipe, these policies still had merits. Through them, India accumulated many complicated capabilities, and would diversify and grow in the future much easier than other developing countries. Besides, the suppressions of labor-intensive industries are mainly owed to labor laws and small-scale industrial policy, and less to core industries policies. Consequently, Felipe el al (2013a, 2013b) supports government intervention to help create core industries and help accumulate capabilities. These capabilities lay a good foundation for further diversification and development, such as China and India did. These two studies are very relevant to this paper, but they both argue directly from macro policy perspective to diversification results. They still cannot elaborate the dynamic process, that how China and India managed to diversify to unrelated core industries. Besides, both China and India are not yet high-income countries. The effects of their remarkable capabilities accumulations from core industries are to be examined by the future.

Similar to product space's national level studies, EEG studies also support there are path dependences of diversification in firm and in region. That is to say, related variety is more prevail and more natural than unrelated variety in firm and in region. In terms of firms, firms tend to diversify to technological related industries instead of unrelated, because they have

built firm-specific routine for years and costly to shift, as well as limited opportunities from regional environment (Boschma & Frenken, 2009). In terms of region, Neffke and Svensson Henning (2008) used Swedish data and found evidence that related sectors are more likely to enter the region, while unrelated sectors are more likely to exit the region. Besides, related variety can also facilitate more knowledge spillover, which is favorable for regional economic growth. Frenken et al. (2007) found out more related variety regions in Netherland tend to have higher employment growths than unrelated variety region. Nevertheless, unrelated variety [5]has not totally been underplayed in EEG studies. The most renowned function of unrelated variety is to absorb sector-specific shocks, and increase region's resilience and stabilize economy on the long run (Essletzbichler, 2007). Moreover, recent studies (Boschma 2015, Coenen el al, 2016) also argue unrelated variety could possibly generate technological breakthrough and new development path, though this process will be unusual. In order to achieve unrelated variety, active policy intervenes are indispensable in the missing supportive environment. Coenen el al (2016) also indicates that current EEG studies have not understood much about diversification process through unrelated variety.

Even though as discussed above, there are growing attentions to unrelated diversify in EEG, EEG's main focuses are still on regional new path development and reviving old industries. These discussions are very suitable for industrialized society. Actually, EEG studies, as author aware (Neffke el al, 2011; Boschma & Iammarino, 2009; Boschma el al, 2012; Essletzbichler, 2007), are all developed countries cases. However, these discussions shed little light for developing countries, which might have never industrialized before. High-income countries already have favorable positions in core industries, such as Sweden, US, Italy, Spain. By contrast, developing countries just occupy the periphery products. Hence, the initial starting point of discussion is quite different between developed countries and developing countries. This is the big blind point of EEG. Majority of manufacturing goods from developed countries are core products. No matter newly emerged or soon obsolete, these core products are still very difficult for low-income countries to produce. However, it is apparently necessary and important for developing countries to eventually diversify to these sophisticated core products, even though these core products are unrelated to their current periphery products at this stage. EGG mainly

[5] From product space measurement, every product is connected to every product but by different proximity, range from 0 to 1; thus, EEG's "unrelated variety" would mean a low proximity in product space.

discuss on regions which already contain complicated capabilities, and discuss how new path could emerge from old path, so it is more like “choice” question. By contrast, for developing countries, diversification is more like a “can or cannot” question. This “can or cannot” situation is most likely to occur in developing countries and rich oil countries instead of high-income countries. To sum up, to study unrelated diversification is not only important for developed countries’ new path development, but also a fundamental question for lag behind countries, in terms of catch up and long term economic growth.

4. Product Space Methodology

Product Space use network theories to reveal the proximity relationship between each pair of products exported in the world. It can also display the comparative-advantage export profile of certain country in a given time. Within the framework, there are three main categories of notions. One is how proximity or relatedness is defined (RCA, proximity, PATH, density). Second is the value embedded in the product (PRODY) and the value of country's export basket (EXPY). Third is the complexity of product (PCI). We will introduce one by one in the following part.

Variable definition

Product Space methodology is developed by Haunmann and Klinger (2006), Hausmann et al (2007) and Hidalgo el al. (2007). Its basic idea is to use export data to find out the possibility of two products will be exported with comparative advantage at the same time.

Revealed comparative advantage

This method use *revealed comparative advantage* (RCA). RCA is the ratio of export share of a certain commodity in one country's export basket to the same share at the world level (Balassa 1965), if the index is larger than 1, we will say this country have revealed comparative advantage in this commodity.

$$RCA_{ci} = \frac{x_{ci} / \sum_i x_{ci}}{\sum_c x_{ci} / \sum_c \sum_i x_{ci}}$$

Proximity

Later on, *proximity* between product i and j, is defined as the minimum of pairwise conditional probabilities of a country export one with revealed comparative advantage (RCA) given that it exports the other with RCA (Hidalgo et al, 2007). For example, among all countries (say 144) in the world, if two products are always export with RCA together in several countries (40), and all

remaining countries (104) neither export any of these two products with RCA, then we could expect these two commodities are very close, and always comes along with each other. Their proximity is 1, the highest among all.

Proximity $\varphi_{i\,j} = min\{P(RCA_i > 1|RCA_j > 1),\ \ P(RCA_j > 1|RCA_i > 1)\}$

After each pair of two products have all been calculated their proximity, network analysis is used to draw a product space, as showed in figure 1.

Relatedness to other products PATH

PATH is a variable developed in Hidalgo el al. (2007) and Felipe el al. (2012). It calculated the average proximity of one certain product to all other products. In this paper, number n will be 754 in 1995. Thus, it is variable to assess certain product's position in the whole product space, to see whether it has close proximity to other product or not. This variable is only relevant to product instead of country.

$$PATH_i = \frac{\sum_j \varphi_{ij}}{n}$$

Here, n denotes the number of all products, j denote all produce within the space except product i.

Density

$$\omega_{i,c} = \frac{\sum_j x_j \varphi_{ij}}{\sum_j \varphi_{ij}}$$

Where x_j *equals to 1 if* $RCA_{ic} \geq 1$*, otherwise equals to 0*

Different from PATH, *density* is a variable both relevant to product and country. Density's denominator is the same as PATH's numerator, which is the sum of proximity between product i and all other products. Density's numerator is sum of proximity between product i and products country c exported with RCA. Density is the measurement of existing export portfolio's distance to a certain product. A high density value indicates that country c has many developed products surrounding this product i. This concept is very relevant to our related

variety and unrelated variety. If a country can only develop new product which has a high density, this means she can only acquire new product which is already surrounded by her existing products. Hence, this country can merely diversify through related variety. By contrast, if one country can diversify to new product with low density, this means this product is rather far away from exiting products of this country. Accordingly, we would expect this country has strong ability to diversify through unrelated variety.

Product export value PRODY

In terms of product's export value, we will use *PRODY* developed by Hausmann et al (2007). For each product, PRODY is calculated as a weighted average of the GDP per capital of the countries that export it, with the weights being value share of this commodity in one country over the sum of value shares across all countries exporting the good. PRODY is the variable representing the income level of that product. A higher PRODY indicate this product is mainly exported by high-income countries, which could indirectly reveal the value insides the product. By contrast, if one product is mainly exported by poor country, we will expect this product is not very complicated, and there is less value embedded in it.

$$PRODY_i = \sum_c \frac{({}^{x_{ci}}/_{X_c})}{\sum_c ({}^{x_{ci}}/_{X_c})} * GDPpc_c$$

Country's export basket value

One step further, Hausmann et al. (2007) use PRODY to create a variable for country called *EXPY*. EXPY is the weighted average of PRODY of the goods that country export with RCA, with the weights being their respective export shared of product, EXPY is an aggregated measurement of the sophisticated degree of country's export basket. This variable is highly correlated with GDP per capita. And this variable could serve as a strong predictor for further GDPpc growth (Hausmann et al. 2007). If a country keep increasing its EXPY values, that means either this country diversify to new sectors with higher PRODY, or increase the export share of current high PRODY product. Thus, we could perceive EXPY as another measurement of economic performance, which is from export perspective.

$$EXPY_c = \sum_i \frac{x_{ci}}{\sum_i x_{ci}} * PRODY_i$$

Thus, economic growth could be understood as diversification process from less sophisticated products to more sophisticated ones, along with higher and higher EXPY.

Product Complexity Index

Besides, based on network analysis, *Economic Complexity Index* and *Product Complexity Index* [6]are also introduced by Hausmann & Hidalgo (2010) as a measurement the complex level for country's capabilities and for each product. The principle behind calculating these two indexes are two: more complicated product is produced in fewer countries; more complicated capabilities country can produce more products. Then these two principles are inserted to each other and keep on iterating. As a result, we get our Economic Complexity Index (ECI) and Product complexity index (PCI). We will use PCI index in this paper.

Critiques about product space

Admittedly, there are several limitations for this methodology. Firstly and foremost, it only contains manufacturing data without service data, while importance of service trade in facilitating economic growth is drawn more attentions (Mishra et al., 2011). Secondly, export data might not necessarily be a good proxy for productive structure of economy. Besides, to different extent, export performance will be impacted by market structure, traded openness, and domestic market size, so it is not only determined by productive capability of this country (Jankowska et al, 2012). Lastly, trade data and corresponding PRODY, cannot reflect the actual distribution of value-added of the final product, because of globalized assembly industries such as Maquila in Mexico and OEMs in China. Hence product space method could get biased understanding towards productive capacities of a country. We acknowledged these limitations. However, to map the global and country product space is not only inspiring but also justifiable. Manufacturing is still the highest productivity sector for most countries, and export activity

[6] Both index are calculated through many steps, will not be showed in this paper. Readers can refer to Hausmann & Hidalgo (2010) for a detailed version or Simoes (2010) for a simple version.

implies the highest manufacturing level of most countries because it has to follow the same international standards (Hausmann et al, 2006). Thus, exporting of manufacturing goods is in the center position of whole economic activities. As results, product space methodology is justifiable and it provides a new to understand economic performance through products.

Data Source

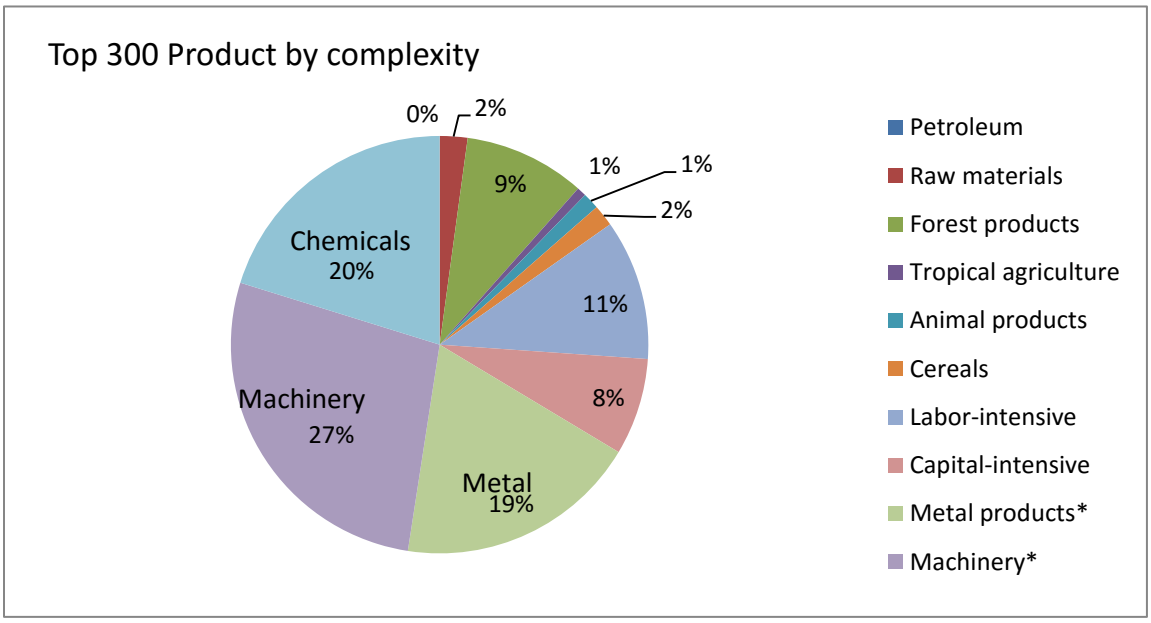
Following other major studies in product space (Hausmann el al., 2007; Hausmann & Klinger 2006; Hidalgo& Hausmann,2009), this paper uses a combination of two datasets that contain 4-digit SITC (Standard International Trade Classification) breakdown of trade data across industries. For historical SITC classification data (1962-2000), this paper relies on the World Trade Flows database (Feenstra et al., 2005). From 2000 to 2014, United Nations Commodity Trade Statistics Database (COMTRADE) data will be used. In both series, the export values measured in current US dollars. GDP per capita is measured in PPP terms with constant 2005 international dollars to make time series comparable. It is taken from World Bank World Development Indicators.

5. Empirical

5.1 Core industries

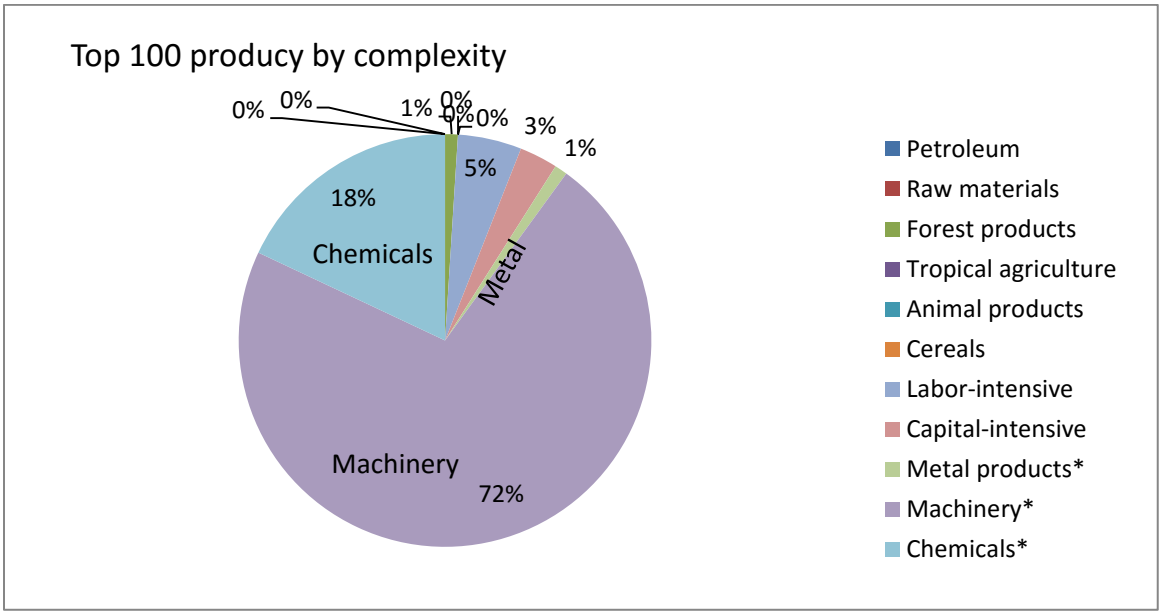
This part will briefly show core industries are important in three aspects, more capabilities embedded, higher export value, and more potential to diversify. The first aspect will be verified by author's calculation, and other two are tested in Felipe et al (2012), and its findings will be summarized in this part.

Figure 4: Distributions of top 300 complicated product by industries



Source: Author's calculations based on Product Complexity Index
Note: *denote core industries (metal, machinery, and chemicals)

Figure 5: Distributions of top 100 complicated product by industries



Source: Author's calculations based on Product Complexity Index
Note: *denote core industries (metal, machinery, and chemicals)

Product Complicated Index (PCI) is introduced in methodology section, and this article uses average value of PCI from 1985 to 2014 to rank the products. Among all 754 products, core industries have dominating advantages in both top 300 and top 100. Among top 300 most complicated products, metal, machinery, and chemical constitute 19%, 27%, and 20%, all together 66% (Compared to their total percentage in all products 46%). Among top 100, their advantages are more obvious, metal, machinery, and chemicals constitute 1%, 72%, 18%, all together 91%. Among top 100, less than 10 products are not from core industries. Figure 4 and Figure 5 show these results. It entails core products indeed are very complicated and require many sophisticated capabilities (Hausmann & Hidalgo, 2010). From another standpoint, countries which can product these products naturally maintain these capabilities embedded in product. It will be easier to produce new product by deploying these complicated capabilities. Actually this is confirmed by PATH data as follows.

Table 2: Average PRODY and PATH for different industries

Industries	Ave. PRODY	Ave. PATH	Rank of PRODY	Rank of PATH
Petroleum	16,352	0.118	3	11
Raw materials	11,228	0.142	9	9
Forest products	15,593	0.175	4	6
Tropical agriculture	8,755	0.16	11	8
Animal products	12,701	0.162	7	7
Cereals	9,089	0.141	10	10
Labor intensive	13,691	0.183	6	5
Capital intensive (exc. Metals)	12,693	0.185	8	4
Core products				
Metal products	15,307	0.204	5	1
Machinery	19,745	0.19	2	2
Chemicals	19,872	0.188	1	3
Sum	14,942	0.171		

Source: Felipe el al (2012:40)

In terms of the latter two aspects, we could refer to table 2, which is summarized from Felipe el al (2012). Core industries indeed enjoy high PRODY, which measures the export value of the product. Metal, machinery, and chemicals have 15307, 19745, 19872 international dollars respectively, dramatically higher than 14942, and only Petroleum(16352) and Forest products (15593) have higher PRODY than metals, but lower than other two. Thus, we could conclude that core industries generally have higher export value than other products. Besides, metal, machinery, and chemical industries have average PATH value as 0.204, 0.190, 0.188, also much higher than all industries average 0.171, and higher than all others industries from Leamer's classification. From this calculation, we could know core industries do have closer connections to other products. As a result, it would be easier to develop new comparative advantage if country is already positioned in core industries, because the "distance" to others is shorter. However, if country has comparative advantage in petroleum, which contains high value, but very low proximity to other industries, it would be very hard to diversify to new activities. It accidently accords with resource curse or Dutch disease studies.

To sum up above, we get robust results about core industries (metal, machinery, and chemicals). Firstly, they are the most complicated products, which imply there are many capabilities embedded in the products. Secondly they represent higher value than other products. Thirdly,

they have closer connections to other products, and easier to diversify to new products. Consequently, in terms of long time economic growth for a country, to diversify to core industries could give countries strong advantages than to other industries. To acquire them means country could produce and export high-value goods (PRODY). Additionally, country would have more capabilities to be used and redeployed; country will be easier to diversify to new activities, which in turn could be explained by more capabilities. This finding is very inspiring, for it highlights the importance of core industries over other industries, and provides three robust facts. For example, one important implication is that core industries do not just have high value, but also contain complicated capabilities and could facilitate further diversification. so it confirms that oil country could reach high income easily, but they may not acquire complicated capabilities, and it would be also difficult transform itself to a diversified economy because of low proximity to other industries.

5.2 Korea diversification

This section will begin with a motivation and a brief review of Korea's economic growth and corresponding studies. Then we will show Korea's diversification pattern, which is intensely towards core industries along its economic growth period. Afterwards, this section will review other studies to provide three qualitative mechanisms for Korea's unrelated diversification, followed by how are they fit into or challenge EEG.

Why Korea?

South Korea was among poorest countries in the world back to 1950s. GNI per capita of Korea was only 1106 USD in 1960 based on World Bank data. Korea had one of world fastest economic growth from 1960s to late 1990s, and maintained momentum in the 2010 (Mah, 2006). Korea became high-income country in 1995 and joint OECD in 1996, which very few developing nations could achieve. Besides high growth rate, Korean development was called a miracle also because Korea developed from a very weak industrial base, no difference to other least developed countries then. From a dominating agricultural economy, Korea quickly transformed to a manufacturing economy, and developed sophisticated industrial capabilities among many sectors, especially heavy and chemical industries. It is a successful nation in economic growth as well as dramatic structure change and product diversification. Hence, it could possibly shed lights on how diversifications matter for economic growth. Other three Asian tigers are not chose because Hong Kong and Singapore are two city states and did not experience much structure change and it is a pity Taiwan is not included in the Product Space database. It could be also very useful to study developed countries, how they diversified from periphery to core products along with economic growth. However global trade data are only back to 1962, when most developed countries are already positioned in core products. And Korea is one of few examples demonstrating a strong shift from periphery to core industries as well as reaching high income level.

There are of course limitations. It is arguable whether Korean's economic growth could be a paradigm. Or it is just a special case, especially when we know most of policy interventions from Korean government were quite successful (Mah, 2006), while those did not apply to most other developing countries (Sanjaya, 2004). However, this paper does not try to find a paradigm or

general lessons, but rather attempt to reveal some mechanisms from Korea to inspire further studies.

Brief economic history of Korea

Japanese colonized period (1910-1945) left Korea peninsula an industrial North while an agriculture South, therefore South Korea's initial economic level was actually lower than North (Amsden 1989). To recover from Korean civil war, Korean government implemented import substitution policy from 1950s to early 1960s to protect infant industries. Over this period, government mainly made use of comparative advantages and promoted labor-intensive light industries, like textiles industries. Later on, Park Chung-hee seized power in 1961, and his regime led Korea to fast growth. 1963-1973 was a period of export orientation under neutral incentives. Korea government realized the benefits of export, such as to gain economic of scale through expanded global market, and then shifted quickly from import substitution to outward orientations (Rodrik, 1995). The next decade 1974-1982 again witnessed export orientation policies but with heavy and chemical industries (HCI) targeting until early 1980s, R&D had not played a significant role in Korean industries, since imitation and reverse engineering were enough for Korean domestic firms. Eventually, 1983-1995 was an era of returning to neutral policies and liberalization, and Korea began to support their own R&D (Ahn & Mah,2007, Kim 1993). In both 1997 and 2008 financial crisis, Korea's economy plunged harshly, but it was also among the quickest nations to recover and regain aggressive growth until recently (Mah, 2010). From 1960 to 2014, Korea's GNI per capital grew from 1121 to 24758 constant USD (World development Indicators, 2016), and experienced a dramatic structure change, transforming from an agriculture economy to manufacturing, and now to service-leading economy. Korea nominal GDP and export value in constant 2005 USD is showed in below figure 6.

Figure 6: Korea GDP and export 1960-2014.

Source: Word Bank world development indicators

Other theories for Korea economic growth

Korean economic growth has been analyzed from many perspectives. For example, Krueger (1985) from market failures, Haggard (1990) from government intervention, Young (1995) and Hsieh (1999) from factors accumulations, Rodrik (1995) from social and political institution. This debate is still going on, and these perspectives have different explaining powers, and in some way complement each other (Garcia-Blanch, 2001). However, there are no studies from perspective of product diversifications. Both EEG and product space perceive economic growth as continually introducing new products and activities. Thus, product diversification perspective might shed new light on economic development. This following part will reveal diversification patterns of Korea, followed by qualitative studies to highlight some possible mechanisms.

Diversification patterns of Korea

1) Products diversification

From the product space, many products had emerged to be comparative advantage in Korea over the years, and the number of products with RCA increases dramatically (*Table 3*). Besides, categories of industries with RCA also noticeably change from primary and agriculture industries to manufacturing industries, especially core industries, metal, machinery, and chemicals.

Table 3: Korea export diversification

Number for products with RCA	1962	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010	2014	Total number of industry*
Petroleum	1	0	1	2	1	2	2	2	3	4	4	2	6
Raw materials	14	14	9	13	7	2	3	4	6	9	8	5	52
Forest products	2	2	3	6	11	6	2	1	1	0	1	2	39
Tropical agriculture	3	2	3	7	7	4	3	2	2	3	2	2	44
Animal products	15	11	10	10	12	11	9	6	7	1	1	2	50
Cereals	6	6	6	6	7	3	6	5	5	6	3	4	74
Labor-intensive	4	16	18	51	55	53	51	31	23	14	9	9	98
Capital-intensive (exc. metals)	2	18	18	32	39	34	42	40	36	32	23	16	72
Core Commodities													
Metal products#	1	10	4	18	35	26	19	17	19	13	16	16	47
Machinery	3	4	7	29	47	39	46	52	48	51	52	52	178
Chemicals	4	2	2	4	7	8	9	14	16	18	25	34	94
Total	55	85	81	178	228	188	192	174	166	151	144	141	754

Source: author's calculations.

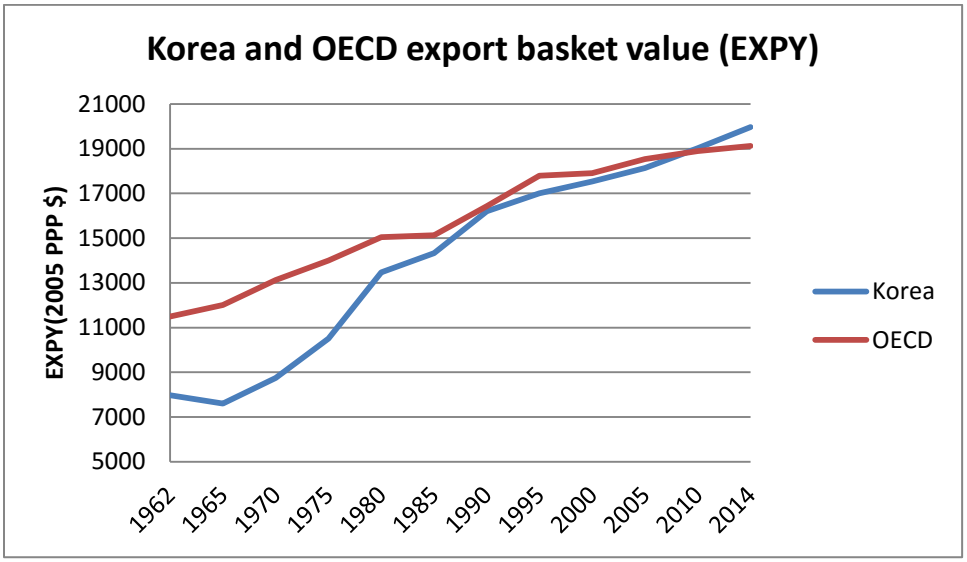
Note: * total number of industries changed based on availability of data, ranging from 689 to 889, here uses number in 1995 as representative.

#metal product belongs to capital-intensive according to Leamer's categories, here to separate them for analyzing core industries.

To be specific, in general, total number of industries with RCA increased from 55 in 1962 to the highest 228 in 1980, and then decrease gradually to 141 in 2014. However, there were quite uneven distributions between industries. Petroleum did not change much, stagnated at one or two among total six products, though reached four in the late 2000s. As for raw materials, forest products, tropical agriculture, animal products, and cereals, all of them peaked at 1980s, then went down, and almost entirely disappear. This is an impressive change given many products choice in these primary industries. It was actually in line with Korea's overwhelming move to manufacturing industries. Labor intensive industries used to be most important sectors for Korea in 1980, there were 55 products had revealed comparative advantage, accounting for 24% of all Korean products, and they occupied more than half (56%)of all labor-intensive products menu. However, labor-intensive industry in Korea witnessed steady decreased to only nine in 2010s. All these changed indicated that Korea's comparative advantage have shifted from primary, agriculture, and labor-intensive industries to more capital and skilled industries, mainly core industries. Capital-intensive manufacturing also enjoyed strong booms from almost none, and then experienced some decease from 1990s and stagnated at still rather high level. Metal products are belonged to capital-intensive industries, but here it is separated to observe its change, and it moves similar to other capital-intensive industries as discussed. However, It is very impressive to find out both machinery and chemicals, starting from extremely low level (3 and 4 in 1962), grew steadily until 2014, and showed no decreasing trend. Numbers of two industries are even higher than many developed countries. Core industries account for 72% all Korean's comparative advantage in 2014, which was only 15% in 1962. Given core industries have three advantageous aspects discussed before, Korea indeed has a great position in product space now, after climbing up from periphery staring point (*Table 3*).

To recap, we could conclude that along with Korea's fast growth from 1960s, Korea also experienced a dramatic industry change, from primary, agriculture to manufacturing products, especially to core industries. There is a considerable stock of metal products as well as large numbers for machinery and chemicals products. Therefore, from product space perspective, Korea had a very successful industry change, diversifying intensely from periphery to core industries. This diversification success can be echoed by Korea's economic growth as well as the value of its export basket.

Figure 7: Korea and OECD export basket value (EXPY) 1962-2014.



Source: author's calculations. *EXPY* is defined in section four; OECD includes only West Europe[7], US, Canada, Japan.

Korea export basket values also rose from 7980 USD in 1962, to 19975 USD in 2014, this is an impressive growth, and not just converged to OECD average in 2010, but also became a leader. Since EXPY is the measurement of export basket value, this graph indicates that Korea's exporting goods' value had kept on increasing along with economic growth from 1960s. This increase was through diversifying to more and more sophisticated core products as showed in *Table 3*, and the formation of Korea's export basket also converged to the global frontier.

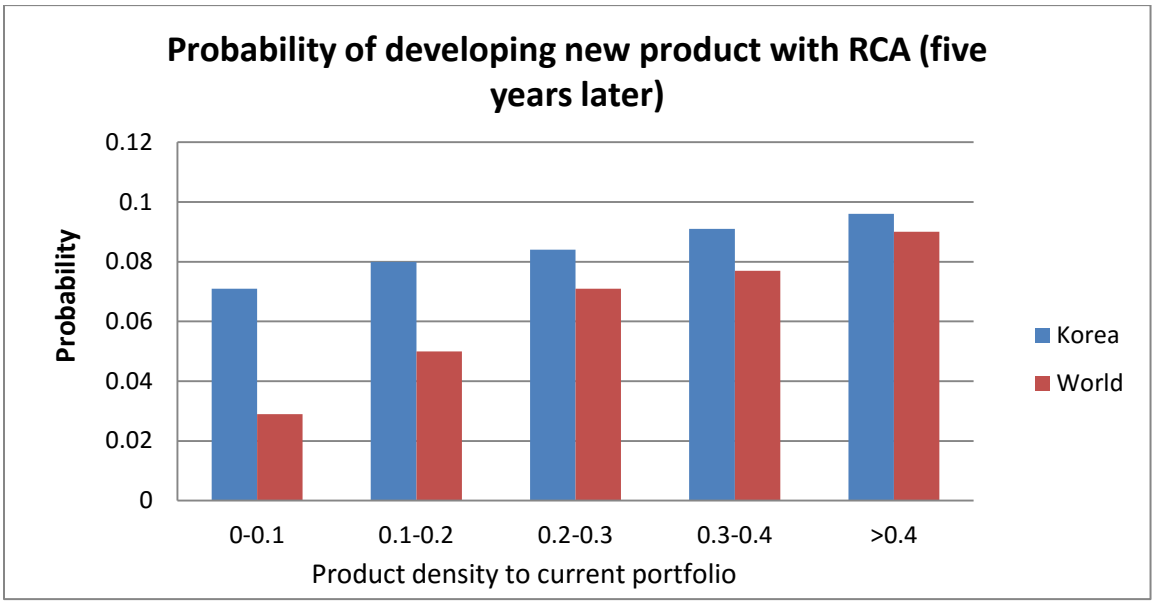
2) Diversification distance

The above results show that Korea diversified to many core industries[8]. Further, In order to understand to which extent Korea's diversification followed path dependence (existing products portfolio) or unrelatedness, this paper calculated the probability of a new product developing RCA given it had no RCA five years before. The result is showed in *figure 8* below. The Y axis is the probability, and X axis is the product's *density,* as introduced before, the measurement of how close this product to this country's existing product portfolio. The higher density means it is

[7] West Europe: United Kingdom, Ireland, Denmark, Norway, Sweden, Finland, Spain, Portugal, France, Belgium, Germany, Switzerland, Austria, Netherlands, Italy.
[8] Appendix figure 9 shows the process visually from product space tool.

quite close to exiting portfolio, while the lower density means it locates far away from what this country produces now.

Figure 8: Probability of developing a new product with RCA (five years later) for different density range in Korea and World average



Source: author's calculations. *RCA* and *density* are defined in section four. Time range is 1985-2000, world includes 72 major export countries[9] (Feenstra et al., 2005)

In terms of general patterns, for both world and Korea, product diversification follows path dependence, because diversified probability is positive associated with density. That is to say, if a product has closer proximity with current export portfolio, it would have larger possibility to be "discovered" (export with RCA) in five years. Existing product structure indeed constrains diversifications. This finding accords with other studies (Hidalgo el al, 2007; Hausmann & Hidalgo, 2010; Boschma &Capone, 2014b). However, there are also two significant differences, 1) in each density range, Korea has a higher possibility to diversify than world average, which confirms Korea's strong ability to diversify to new products. 2) Korea seems to be less constrained by path dependence than world average. Korea and world have similar probability

[9] For detailed country list, please refer to Feenstra et al., (2005:3) Table 1. In order to calculate, this paper splices Belgium-Luxembourg (1984-1998) with Belgium (1999-2000), South Afr.Cus.Union (1984-1999) with South Africa (2000), and deletes former Czechoslovakia, former Federal Germany (1984-1990), former USSR (1984-1991), former Yugoslavia (1984-1991).

to diversify with the higher density, where the new product is very close to existing products. Though, with the lower density, Korea had a much higher probability to diversify than world average, and just a little bit lower than its probability in high density. That is to say, far away product can also be discovered in Korea, but not much in world. To sum up, world tends to follow more path dependence, and even get trapped in its "nearby" products. By contrast, Korea has an impressive performance in its diversification. Korea tended to diversify to more product than world average in every range of density. Also, it was constrained less by product path dependence, and could diversify strongly to unrelated products through a long "distance".

From the perspective of product space, above part provides the impressive diversification patterns of Korea. The strong diversification ability and mainly towards unrelated core industries can be important reasons to understand Korea's durable economic growth. In the following part, we will discuss the crucial question, how Korea managed to diversify to unrelated core industries, in order to highlight some possible mechanisms to inspire further studies, especially for developing countries.

5.3 Qualitative studies of Korea

This part will provide three studies to enlighten how Korea could diversify to unrelated core industries. And we could draw some lessons from these cases. All three cases will endeavor to elaborate from micro firm perspective and underline the mechanisms of knowledge creation, knowledge transfer, and firm branching, to conform to EEG perspective.

1) Korea Chaebols

Similar to Zaibatsu in Japan, Korean chaebol is family-controlled conglomeration having high degree of diversifications (unrelated products) and high degree of coordination. Famous Korean chaebols for example, are Samsung, Hyundai, LG, Daewoo, etc. Chaebols are the dominating force in Korean economy. For instance, top five chaebols accounted for 10% of Korean total GNP and top 30 accounted for 16% in 1995 (Chang, 2003). This part will review how chaebol structure interacted with other factors, such as low level of expertise in firm, public financial support, and government disciplines, together contributing to success in unrelated diversifications.

From firm level, based on Amsden's (1989) detailed studies, chaebol's diversifications were far from strategical choice, but rather passive. They diversified to other products mainly because they have to sustain their current productions. This natural unrelated diversification has reasonable background. Diversification patterns are quite different between technology frontier country and late-industrializing countries (Chandler,1992). Diversifications of former countries, like US, mainly go into related fields because firms' competitiveness is built on expertise in technological or marketing. Nevertheless, for late industrializing countries, their expertise was not fledged, and their experience in specific industries could not guarantee firms to develop related products or process, or create high value-added niche. Instead, they tend to diversify to unrelated areas, and competed by price at bottom and at unrelated markets. For Korea, most diversifications were just from demands of current business or entrepreneur's perceptions of potential profits, including unrelated core industries. There were not much vertical or horizontal integration in Korea compared to mature market (Amsden 1989:151). For example, Lucky-Goldstar (LG) group diversified to areas partly because it needed sustainable supply which cannot be satisfied by local supplier, but new activity did not have technological relatedness to its current productions. LG's business diversified initially from cream to plastic, then to electronic, then to oil refining, and then insurance (Amsden 1989:126). Besides, other factors, such as market size was too small and too risky to specialize, also encouraged chaebols to diversify to other industries, related and unrelated. From the above studies, we find out Korean's chaebol would naturally diversify to unrelated industries given their industries base and expertise were not fledged, as well as too small market and risk-diffusing considerations. Compared to their counterparts in developed countries, chaebol's choice did not seem to be sophisticated and even passive. They tended to diversify to more unrelated industries and compete by price at bottom to survive. However, this seeming chaotic unrelated diversification laid a good foundation for economic growth, especially when their expansions reached into core industries.

Another question will be naturally asked, even though we know that chaebol was inclined to diversify to unrelated industries intrinsically, *how can they manage to develop so many unrelated fields successfully*? For the core industries, governmental financial support was essential for chaebol to acquire technology, such as HCI policy. Over their initial take-off, chaebols purchase varying industry-specific expertise from abroad, largely supported through credit guarantees and subsidies by government. These strong public supports facilitated both

capabilities accumulations and fast diversifications. In terms of capabilities building, because government implemented strict disciplines of rewarding winners and punishing losers through export competition (e.g., worst chaebol may die out), so chaebols had to absorb these tacit technological knowledge locally to compete in export. From this pressure, chaebol began to develop their own abilities (Adam & Davis 1994, Lall, 2013, Hausmann & Rodrik 2003). In terms of diversification, because of the cheap technologies, firms could keep new investment cost to minimum, and new affiliates could operate in a light financial burden. Moreover, also due to governmental financial support, chaebol does not need to exchange family control for financial access, thus chaebol was still controlled firmly by family. There is of course shortcoming of family controls, but it was beneficial for chaebol to coordinate different resources within the big firms to serve different subsidiaries at best. The central "brain" and uniform culture added coherence to these diversification, and general abilities (feasibility studies, task force formation, equipment purchase, etc) were easier to circulate within one chaebol. Actually, most diversifications within the chaebol was based on task force from existing group and coordinated by chaebol leader, and this process might base on technological relatedness (shipbuilding to automobile) or unrelated but merely management skills (construction to shipbuilding) (Amsden 1989:128). To summarize, in terms of our studies, we could conclude there are four factors: 1) government financial support to technologies, 2) low level of expertise for late industrialized countries and firms, 3) chaebol's family control, 4) government strict export disciplines. It is the four factors interacted and catalyzed chaebol's diversification to many related and unrelated activities, and also maintained success in the long run. Actually many unsuccessful chaebols had already died out by government discipline (Lall, 2013).

To recap, we could know it was the four factors functioned together as a mechanism for Korea chaebol to diversify to unrelated industries and maintain successful. Government financial support to acquire technology was just one part of story. Thus, in terms of policy implication, it would be very hasty if here we recommend countries to follow Korea, to import mature technology, and promote large firms to internalize the technology by public financial support, such as HCI policy of Korea. Rather we should bear in mind the mechanisms why (low expertise, passive diversify) and how (family coordinate, lower financial burden, and government discipline picking winners) chaebol diversify to unrelated core activities.

Moreover, without comprehending mechanisms, these policies might even backfire the economy. Since development paths are very context based, and institution plays a crucial role in the evolution process (Acemoglu el al, 2005). Actually most Latin Americans indeed also implemented Import substitution policy (ISI). However, these governments were mostly reluctant to implement strict disciplines to push firms to really accumulate capabilities, improve quality, and compete with each other. For example, Latin American failed to use export as a selection order, a method firm has to meet international standard (Hausmann & Rodrik, 2003). The reasons behind this mainly owe to firstly, government's populism policy to delay the competitions for constituency, and populism was originated from political system and unequal society. Secondly, politicians join clans with firms, which benefited from this ISI (Adam & Davis 1994, Lall, 2013 2004,Jankowska et al, 2012). Thus, only when we could understand why Korean government implemented strict disciplines to firms, policy implications, by considering social-institution context, would be meaningful.

Finally, this chaebol study also confirms that EEG's micro foundations are very important. Since regional branching's object is firm, thus special feature of chaebols could be used to understand diversifications. Chaebol's diversification is almost all internal branching, instead of other three channels of knowledge transfer. The above case at least could identify one reason, family coordination is easier for chaebol to internalize multiple tasks' externalities, and knowledge spillovers were captured within the chaebol, and diversify within the firms. This case could briefly answered Haussman &Klinger (2007) question whether chaebol is good to internalize the externalities and easier to diversify. In another way, chaebols' diversifications did not seem to be bounded in region or city, for example, Hyundai headquarter in Seoul, Hyundai Motor in Ulsan, Hyundai steel in Ulsan. This phenomenon could be explained from Boschma (2007), that strong organizational and institutional proximity in the chaebol indeed substituted geographic proximity, and facilitate diversification. Again, family control of chaebols provides a natural close network system as well as common habits, routines, established practices. Lastly, Korea chaebol initial diversification challenges EEG's technological relatedness. Korea's diversifications were more need-based and profit-seeking, and even diversify to unrelated variety. This unsurprisingly accords with Chandler's (1992) distinguishing late industrializing country from technology frontier countries. Late industrializing countries did not have much expertise to build on, so their diversification depends less on technological-relatedness. For developing countries,

their diversification mechanism might be quite different, and technological relatedness does not rule, which is also discussed by Tanner (2014).

To recap, this part highlights how chaebol manage to develop capabilities and move into far-away core industries, with delicate interaction with public financial support, government discipline, and low level of expertise. It is hard to give any policy implication because this case reveals a delicate mechanism, and there are undiscussed institutional settings behind. Besides, we also indicate how EEG could complement to understand this micro process as well as how chaebol case challenges EEG in turn. EEG could be expanded to inter-regional level, and moves beyond technological relatedness, and show more attentions to late industrializing countries.

2) Stepping-Stone industry

Industries with comparative advantages may not helpful for diversification, and they could be isolated in product space. This case will show cotton textile, Korea's most popular industry, was not the springboard for further industrialization. However, Korea's quick diversification originated from early import substitution heavy industries projects, such as cement. Thus, we argue there might be some stepping-stone industry which can breed further diversifications but not necessary is this country's comparative advantage. Consequently, developing countries can step into this stepping-stone industry for further diversifications.

Even though cotton textile industry accounted for around 20% of GNP of Korea in 1950s, however, it was not important for further diversifications. With the responses of Korean chaebols, they prevalently claim cotton textiles industries were not important, and transferred little know-how, skilled people, or organizational linkage to new industries (Amsden, 1989:246). Thus this response strongly refuted neoclassic understanding of automatically industrial shift from textile industries to a little bit more capital and less labor industries. It is not surprising actually textile industries cluster overwhelm in the right side of space (*Figure 1*). It is not just periphery but also isolated, and textiles need to overcome a big gap to reach any other products. Back to Korea, the new business groups emerging from chaebols were directly or indirectly from government's early import-substitution industries. These basic industries are generally heavy industries, including cement making, sugar refining, fertilizer manufacture, oil refining, and construction projects. These findings by Amsden (1989) highlight the importance of certain

industries, mainly heavy industries, over others, and it accords with product space studies twenty years later.

What are the specialties of heavy industries over others? Amsden (1989) provides a learning process understanding. Firstly, heavy industries require different resources in technical and management, especially more trained engineers who know scientific and codified knowledge. It would be easier to apply capabilities embedded in engineers to other industries, because knowledge is codified and scientific. Secondly, since these capital-intensive industries mainly compete on capital efficiency, firm tends to adopt "state of the art" technology while light industries compete on labor. Hence, there is constant introducing of new technology in firms. Firms and workers have to adapt to it, so capabilities were forced to be accumulated stepwise. And these capabilities are both sophisticated and universal, could be applied to many other industries. For example, chaebol Hyundai's diversification mainly originated from its cement mill, where founder of Hyundai trained his managers on quality and process control, inventory management, etc, and then deployed them to other diversified subsidiaries (Amsden 1989: 267).

To sum up, heavy industries' knowledge feature and its competing modes force firms to accumulate knowledge sophisticatedly and deeply. Therefore, by introducing one or two heavy industries from import substitutions, most of these capabilities could be grasped somehow, like the case in Korea. Then these capabilities would be helpful for further diversification, even a self-enforcement process. By contrast, light industry has a very different learning process from heavy industries, and it is harder to gain capabilities needed for other industries, especially core industries. Thus, because of the different capabilities embedding in different industries, to merely rely on market to diversify from light manufacturing seems to be extremely difficult without extra help. Therefore, this paper brings support to structuralism, which claims governmental intervention is important and indispensable. This paper would claim that in order for long-time economic growth, to help create some skill-intensive and capital-intensive industries, like heavy industries, are not sufficient but necessary. However, the rationalities behind the intervention lie in creating capabilities instead of creating the industries per se. More importantly, how to make use of these capabilities by different actors, and to lead them to new activities are very crucial, and have not been discussed enough here. It is noteworthy that Korea's example does not verify that import substitution industries could absolutely lead to diversifications, for there are many other factors underlying this process.

Finally, inspired from the case of Korea and product space methodology, this paper further argues there might be "stepping-stone industry", which defines an industry lies between core and periphery industries, and serve as a diversified hub. Stepping-stone industry would be near to periphery products, but also contain some capabilities core industries required. It would be easier for developing country to occupy stepping-stone industry by intervention, and then this industry could possibly serve as an incubator for more diversifications. For example, both Hyundai and Ssangyang chaebols used cement as stepping-stone for diversification. This qualitative finding indeed matches with product space measurement, that cement lies between cotton textile and machinery in product space (figure 1).

If stepping-stone industry indeed exists, more importance questions would be 1) which industry could be stepping-stone, 2) the mechanism behind stepping-stone industries. The first question could be carried out from product space. This industry is most likely to be in the center right part of product space, where is in the middle between core and periphery products. This region is mainly occupied by *construction materials and equipment* (Red bubble in central right of figure 1), and actually cement industry in above case belongs to this category. Then panel regressions can be carried out to verify whether country which could step into *construction materials and equipment* will have higher possibility to reach core industries or economic growth. The second question is more essential. It could only be studied from EEG perspective, to understand certain industries' specialties for firm behavior and knowledge transfer. For example, cement industries could provide general capabilities for many modern industries, and this knowledge was circulated in chaebol, and was utilized in new afflicts. Which other industries also provide general capabilities for modern industries? And How Korea managed to diversify from cement to core industries while other countries failed? These further questions can be studied in the framework of EEG.

3) Public-Private R&D cooperation

Former two cases discuss how chaebol and stepping-stone industry can help facilitate more diversifications, and especially to core industries in Korea. These two cases are mainly from firm's perspective, and also HCI based. While this case will shed more lights on public sector, and discuss public involvement, especially public-private R&D cooperation in creating

semiconductor industry (also belongs to core industry) in Korea. This part will emphasize that public sector can also play a fundamental role in unrelated diversifications.

In terms of electronic industries, it is only in middle of 1970s Korean government perceived as priority industry like HCI before. The background was in this period, Korean firms encountered pressures from internal and external sources. These pressures included rising wages, foreign firms reluctant to transfer technologies, and WTO new rules in preventing subsidies to specific industries. Besides, Korean firms cannot get stable semiconductor supply from Japan, so there was a strong impetus to accumulate knowledge and localize the technology (Ahn & Mah, 2007).

The rapid development of semiconductors lied in three aspects, 1) public investment in research and production, 2) private firm gained frontier technology, 3) private-public cooperate in research. Firstly, as strategic industry perceived by Korean government, fourth five year plan (1977-81) selected semiconductor industry as industrial priority. A lot of investment was put into this huge capital technology industry (Mah, 2007). This period public investment mainly went to basic research and production facilities. Secondly, in the early 1980s, global recession attacked many small US semiconductor firms in design and processing. In this point, Korean chaebol purchased these firms with strong financial support from Korean government (Lee &Lim, 2001). With these design and processing knowledge, Korean chaebol could jump into higher-value from assembling. Thirdly and foremost, the founding of Semiconductor Consortium was the symbol that Korea moved from learner to innovator. This consortium consisted of threes chaebols, Samsung, LG, and Hyundai, and two public research universities, and coordinated by Electronics and Telecommunications Research Institute (ETRI), a government-sponsored institute. This consortium was essential for almost all major innovations in Korean semiconductor industry, including 16M/64M DRAM, which enable Korea to compete with other technology leaders (Kim, 1998). Within the consortium, the budget was firstly mainly from public sector and then fairly shared by public and private sectors. With the various innovations, Korean semiconductors industries became leader in market (Song, 2005).

To sum up, from assembler to learner, and finally to innovator of Korean semiconductor industries, public strategic support played a strong role in developing this industries. Its contributions were in all three aspects, pubic investment in basic facilities, financial support to private firm, and private public cooperation in R&D. Thus, at least from Korean case, we could know how positive government policy could facilitate branching.

Product space can reveal the unrelated attribute of Korea's electronic industries. Korea did not have any comparable advantages in electronic until 1972, while there are 14 industries in 2014 (*Appendix figure 1*). Electronic locate at the up left region of product space, and in 1970s, Korea mainly had comparative advantages in textile industries, which was on very right of product space. The distance between these two industries are extremely long, or in other words, they are unrelated. However, Korea proved a classic example of unrelated diversification, not based on comparative advantages, but with government involvement. Besides, electronic also belongs to machinery categories. As the three merits discussed in section 5.1, we could conclude Korea made a meaningful unrelated diversification. Thus, this article will argue public sector involvement in certain industry can indeed breed new industries, which might be totally unrelated to old industries. This finding supports government active involvement into certain industries' knowledge creation and transfers. However, the essential micro mechanism, like how knowledge was created from public and transferred efficiently to firm, could only refer to EEG for deep understanding.

In terms of EEG, Tanner (2014) indicate current EEG studies emphasized too much technological relatedness through industrial actors, and nonindustrial actors like universities and research institution are somehow neglected. Indeed, development of semiconductor industries in Korea exactly supports this opinion, and also proved that unrelated diversification can be achieved. Public research could be incubator of new activities, and not necessarily from technological related actors. However, there is still some process not very clear. For instance, inter- region diversification is one question. Korean semiconductor industries predominated cluster in Seoul (Invest Korea, 2015), while the consortium ETRI is located in Daejeon (ETRI, 2015), how does the knowledge created in consortium transferred to firm over long distance? Arguably, the possible explaining could be that the distance is only around 140 kilometers, so Seoul and Daejeon can still be treated as one region. Otherwise, it could be another example that organization proximity substitute geographic proximity, since three chaebols were directly involved in consortium and could utilize the technology immediately.

6. Discussions

This part will discuss the limitations of this research, followed by some implications for developing countries and possible further studies. Finally, this part will discuss how this paper's findings challenge EEG and some potential expansions.

Limitations

It is acknowledged there are a few limitations of this paper. Three case studies reveal how Korea managed to diversify to unrelated core industries. They were indeed inspiring, but they only cover one country. Moreover, the choice of Korea is also limited in terms of Korea is a small country with homogeneous people, relatively high literacy rate from take-off, and very equal wealth and land distribution at beginning of development (Adam & Davis, 1994). Thus, some policy and mechanism can function in Korea might not work the same in other countries. As a result, these studies, based only on Korea, are hard to receive a general rule for development from diversification perspective. In order to achieve a solid conclusion, more rigorous studies covering more countries should be carried out to address this research question.

Implications and future studies

At first, core industries analysis supports the legitimacy of government intervention. Given the three merits of core industries, development path could be understood as diversifying from periphery to core industries. However, for most developing countries, the distance from their periphery to core regions is very long. Hidalgo el al (2007: 486) has done simulations and find out developing countries are hard to reach the core if they only diversify a short distance every time. Thus, it would be suspicious that merely laissez-faire policy or to follow path-dependence is sufficient for development. As for firms in developing countries, their capability in periphery products is very unique and is hard to be deployed to other industries, especially to unrelated core industries. In order to break the dismal future of developing countries, government intervention to create capabilities seems indispensable.

Consequently, how to manage to create capabilities and diversify to unrelated core industries, Korea's cases indeed highlight some paths and micro mechanisms for this research question and

further studies. Firstly, the delicate interactions between Korea conglomerate and government was enlightening. However, the focus should not only turn to government support in acquiring foreign technology or chaebol family control, because there are four factors function together. The opposite example is Latin American countries implementing ISI, but reluctant to carry out strict discipline to force firm to accumulate capabilities. Korea's underlying mechanism inspires that we need context-based delicate solution to different region and country, especially considering the institutional arrangement. Secondly, current comparative advantages industries might not lead firm to further diversify. Korean cotton textile did not transfer much useful knowledge for stepping into other industries. However, cement industries, which contain much know-how, general skills for modern industry, functioned as an incubator. Thus, there might be stepping-stone industry which is not very difficult, but contains more capabilities other industries need than comparative advantages industry, and can serve as an efficient channel of diversification to unrelated core industries. This hypothesis also accords with observation from product space. Further studies could attempt to identify and test stepping-stone industry hypothesis. If yes, it is advised that developing country could step in stepping-stone industry. However, we should be cautious before we understand the mechanism why stepping-stone industry transfers knowledge efficiently, like Korean cement industry, and also aware there are many other factors underlying the diversification process. Lastly, inspired from Korea's semiconductors industries, we know that public research and investment could be another way to promote branching, not just from technological related actors. It gives support to governmental strategic investment in certain industries, even though it is unrelated at this stage. Nevertheless, it is more important to learn from Korea about the process, that how public sector and private firm cooperate, transfer knowledge, and promote innovations, which needs more understanding beyond this paper.

Evolutionary Economic Geography studies

As discussed in this paper, EEG would be a great complement by providing the clearer micro foundation to product space methodology. In most cases as reviews in above Korea cases, we could know EEG generally provide a clear mechanism how Korea firm learn or create knowledge

and conduct new activities. However, three case studies also somehow challenge EEG, and there might be a blind point or a gap EEG theory can fill.

Firstly, it would be a breakthrough to study core industries in EEG. The aim is to understand why metal, machinery, and chemicals industries are different from other industries, which has never been discussed in EEG. This article already displays three aspects, especially through PATH variable we know they tend to facilitate more diversifications, which is very relevant to EEG regional branching. However, this paper carry out through product space method, totally data-driven, and we still don't know why in micro firm level these firms are special. One possible explaining is the attribute of knowledge and competing mode matters.

Secondly, EEG should break away from Euro-centric view, and show more attentions on developing countries. For most of them, unrelated diversification is of great importance in terms of economic growth. Apart from very few resource-based situations, whether or not countries and regions could diversify from periphery products to core industries is directly relevant to development. And this process is inherently involved with unrelated variety, as identified by product space.

Thirdly it might be important to expand spatial dimensions in EEG. From Korea case studies chaebol, stepping-stone industries, and semiconductor development, all indicate that knowledge transfer were not totally bounded in region, and to a certain extent were inter-regional branching. Arguably, this could be understood as organizational proximity and institutional proximity replacing geographic proximity. Inter-regional branching studies would be very important, since most developing countries have more uneven distribution of resources, and the typical situation would be firms and research institutes all cluster in capital. It would be beneficial to understand how remote regions in developing countries, can also benefit from outside knowledge, and enrich the diversities of local businesses.

Lastly, conforming to Tanner's(2014) finding in fuel cells industry, Korea semiconductors industry also indicate that nonindustrial actors, like research institute can also to a large extent facilitate new activities. Besides, both semiconductors industry and chaebol's initial diversifications to catch every opportunity were generally unrelated to existing products. Thus, EEG could expand its research domains beyond the scope of technological relatedness and also pay more attentions to nonindustrial actors.

7. Conclusion

To sum up, this paper attempts to tackle a neglected question by diversification literature, which is how developing countries can diversify to unrelated core industries, namely metal, machinery, and chemicals industries. After Product Space method reveal the dichotomy mode in both products and countries, as showed in *figure 1*, there is a clear gap between core and periphery industries and between developed and developing countries. This paper provide three aspects to show why core industries are special, namely more capabilities embedded, higher export value, and more potential for further diversification. All these three advantages are closely relevant to economic growth, and it is echoed with the fact all high-income countries, except oil countries, are positioned mainly in core industries.

Consequently, this paper motivate it is essential for developing countries to diversify from its periphery industries to unrelated core industries as a process of economic development. As far as author is concerned, there is no former research from development perspective to study diversification. This article applied EEG as complement to Product Space because they both hold evolutionary view and concern about diversifications, and meanwhile EEG can provide micro foundations which product space lack. South Korea provided a great example to study unrelated diversification, since Korea indeed experienced dramatic shift from periphery products to core products in a rather short time. Korea also tended to follow less path dependence, and diversify more to unrelated products than other countries in the world. In terms of Korean case studies, chaebol's interaction with supportive government, stepping-stone industries by import substitution, and public-private research cooperation provide three perspectives to explain Korea's unrelated diversification. All three examples underscore active and positive role of government. Considering the long distance between periphery and core industries and inspired from Korean diversification process, this article argues that government intervention is necessary to help create capabilities for firms or region to promote diversifications and economic growth. However, Korea cases also display how these public involvements interacted delicately with other actors in certain institutions. Thus, it is crucial that public interventions are delivered contextual based, especially according to corresponding institutions.

After highlighting the importance of delicate contextual policy, this paper also challenges EEG studies. EGG could understand majority part of Korean stories, in terms of branching, knowledge transfer. However, it has some blind points. Currently, EEG has no studies in developing countries, and rarely originates from development angel. It is also overly emphasize industrial actors, technological relatedness and intra-regional branching. Arguably, EEG could expand to nonindustrial actors, need-based diversification, and inter-regional branching. Lastly, it is pity that EEG has no studies in terms of core industries, or generally certain industries could be very different from others in terms of economic values and diversification.

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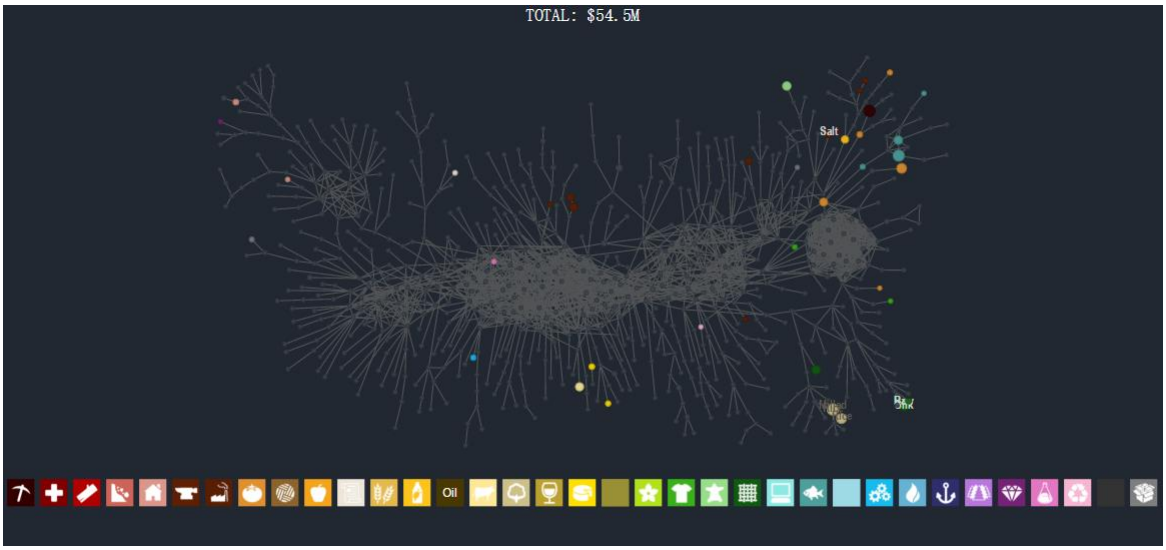
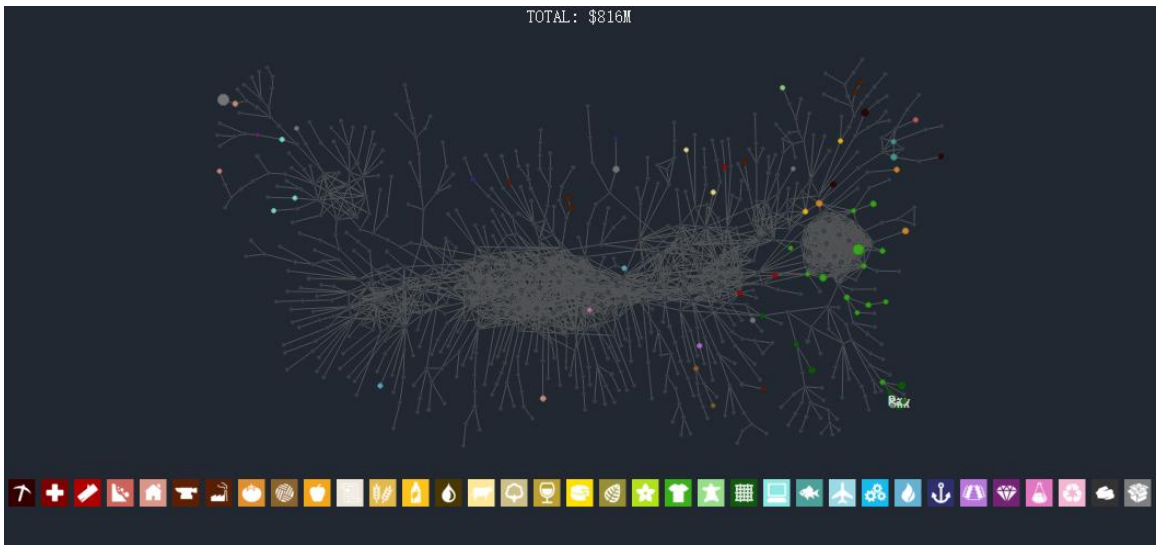
Appendix:

Appendix Figure 1: Evolution of Korea's Product Space

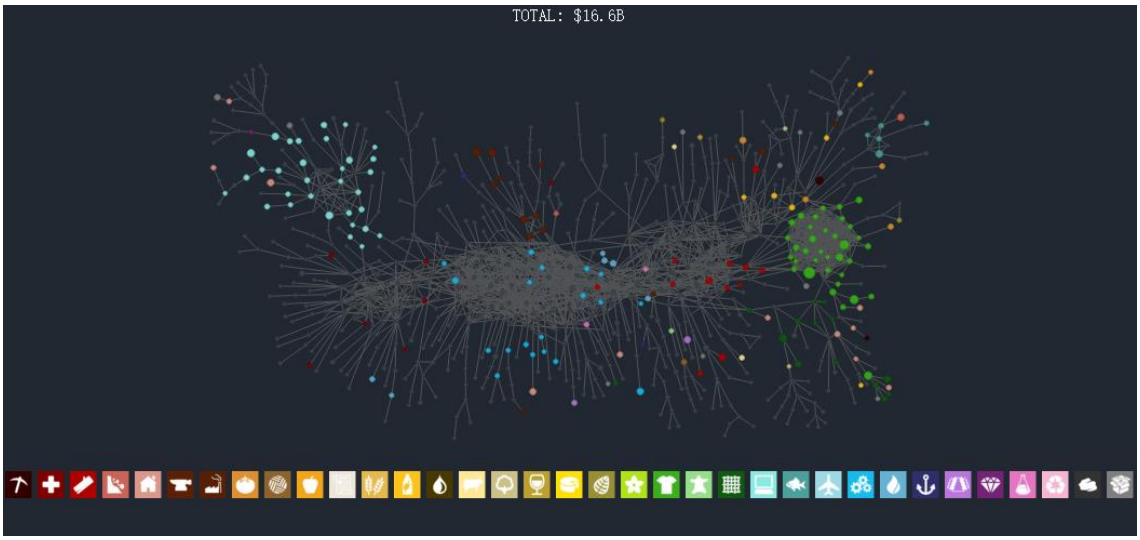
1962



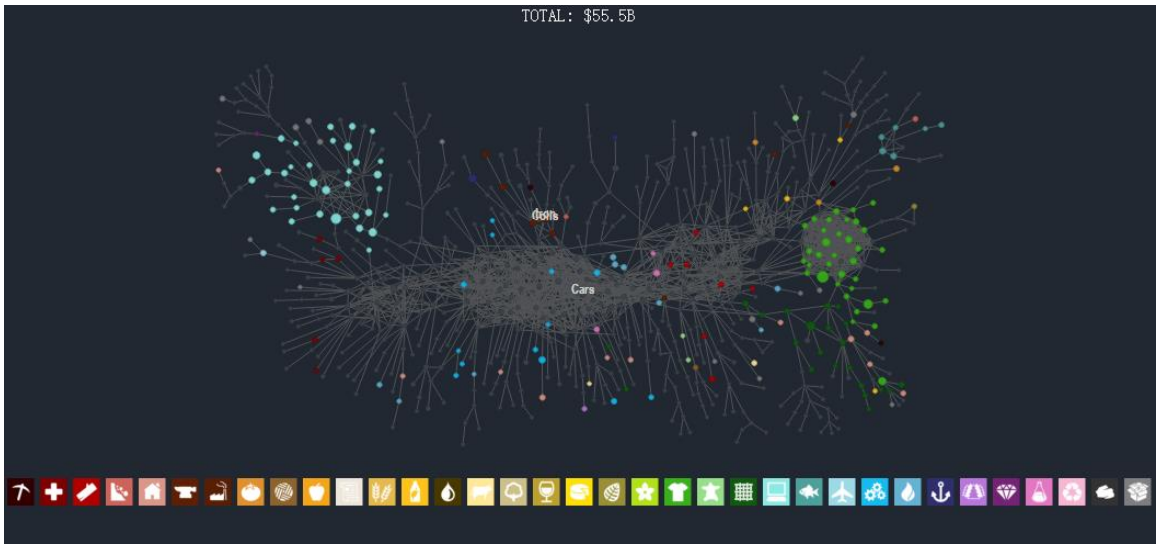
1970



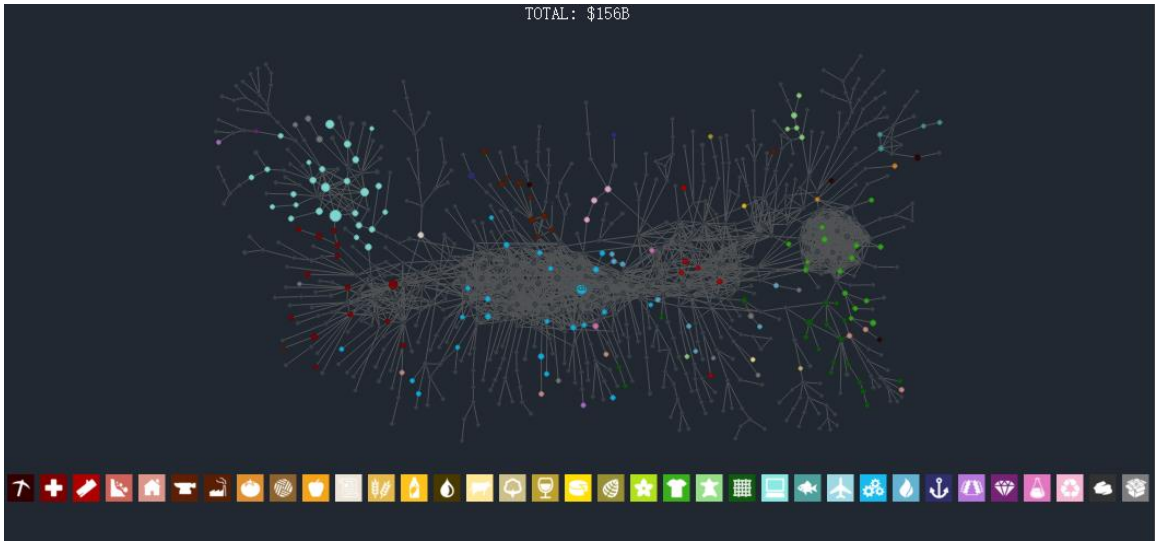
1980



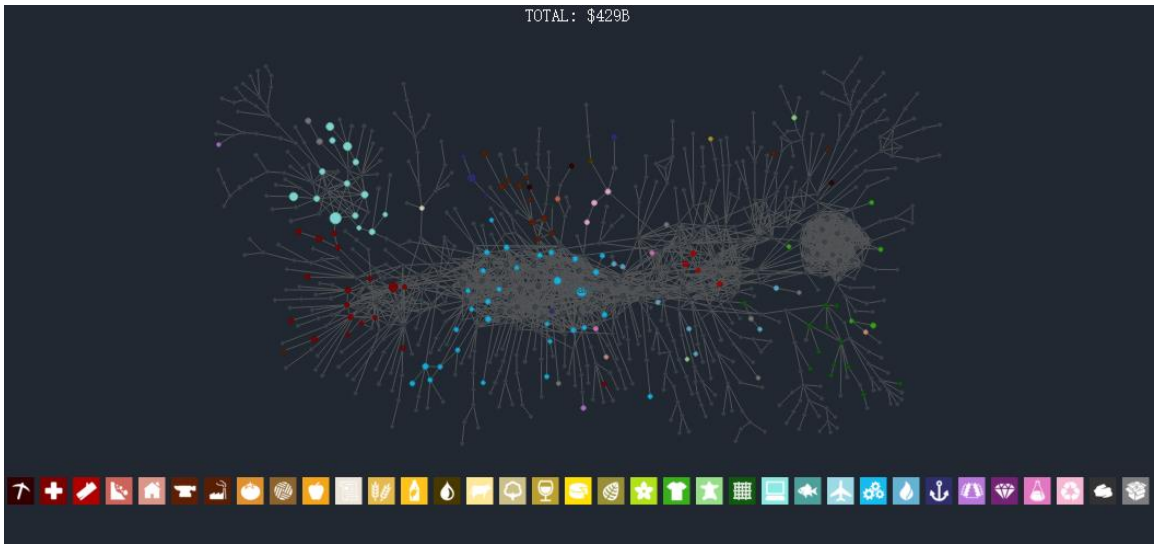
1990



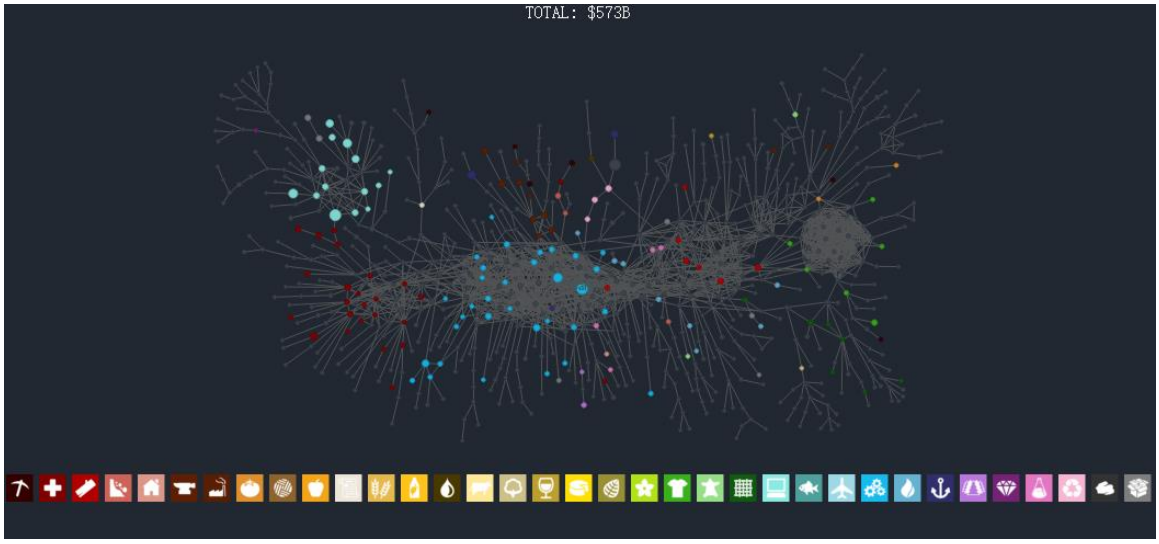
2000



2010



2014



Source: Simoes (2010)

Appendix Table 1: Leamer's Classification and SITC Rev, 2 (2-digit)

1.Petroleum		**7.Labor-Intensive**	
Petroleum and petroleum products	33	Nonmetallic mineral	66
2.Raw materials		Furniture	82
Crude fertilizer and crude minerals	27	Travel goods, handbags	83
Metalliferous ores	28	Articles of apparel	84
Coal	32	Footwear	85
Gas	34	Miscellaneous manufacture	89
Electric current	35	Postal packages, not classified	91
Nonferrous metals	68	Special transactions, not classified	93
Gold, nonmonetary	97	Coin(other than gold coin)	96
3.Forest products		**8.Capital-intensive**	
Cork and wood	24	Leather	61
Pulp and waste paper	25	Rubber	62
Cork and wood manufactures	63	Textile yarn, fabrics	65
Paper	64	*Iron and Steel*	67
4.Tropical Agriculture		*Manufactures of metals, nes*	69
Vegetables and Fruit	05	Sanitary fixtures and fittingsf, nes	81
Sugar	06	**9.Machinery**	
Coffee	07	*Power generating*	71
Beverages	11	*Specialized for particular industries*	72
Crude rubber	23	*Metalworking*	73
5.Animal products		*General industrial*	74
Live animals	00	*Office and data processing*	75
Meat	01	*Telecommunications*	76
Dairy products	02	*Electrical*	77
Fish	03	*Road vehicles*	78
Hides, skins	21	*Other transport equipment*	79
Crude animal and vegetable materials	29	*Professional and scientific instruments*	87
Animal and vegetable oils and fats	43	*Photographic equipment*	88
Animals, live(nes)	94	*Armored vehicles, firearms, and ammunition*	95
6.Cereals		**10.Chemicals**	
Cereals	04	*Organic*	51
Feeds	08	*Inorganic*	52
Miscellaneous edible products	09	*Dyeing and tanning*	53
Tobacco	12	*Medicinal and pharmaceutical*	54
Oil seeds	22	*Oils and perfume*	55
Textile fibers	26	*Fertilizers*	56
Animal oils and fats	41	*Explosives*	57
Fixed Vegetable oils and fats	42	*Artificial resins and plastic*	58
		Chemical materials, nes	59

Source: Leamer (1984). *Italics* are core products. Metal products include *Iron and Steel (67)* and *Manufactures of metals, nes (69)* according to Hidalgo el al. (2007) and Felipe el al. (2013a).