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Economic Analysis of Industrialization, Industrial Structure and Industrial Upgrading

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Economic Analysis of Industrialization, Industrial Structure and Industrial Upgrading

（産業化、産業構造とその高度化に関する経済分析）

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Preface

This dissertation is a summary of my research results at the Graduate School of Economics in Ritsumeikan University, Japan. Many kind-hearted people gave me a great amount of help, professional advice and encouragement. Here, I would like to express my sincere gratitude to them.

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Abstract

This dissertation investigates the industrialization process (the transformation of economic activities from the primitive production to the industrialized production) with production differentiation in national economies, and industrial structure and industrial upgrading (the transformation of economic activities from low-tech to high-tech production) in regional and urban economies. It consists of the following five chapters.

Chapter 1 explains the backgrounds of industrialization, industrial structure and industrial upgrading in Japan and China, reviews the related economic literature and describes the purpose and organization of this dissertation.

Chapter 2 revisits the industrialization model of Murphy et al. (1989) (MSV) to illustrate their main points. That is, once the first industrializing sector has a positive profit, due to the existence of aggregate demand spillovers, the profits of industrialization will increase with the industrialization level, leading to a self-sustaining industrialization process. It then takes the production differentiation analysis into consideration using the Dixit-Stiglitz (1977) monopolistic competition framework. It shows that with high product substitutability, industrializing sectors would cut their prices and steal the sales from their competitors, leading to a business-stealing effect. Moreover, if this business-stealing effect dominates the aggregate demand spillovers, the profits of industrializing monopolists will decline with the industrialization level, and the industrialization process will not be necessarily self-sustaining, which suggests two neglected industrialization patterns: partial industrialization and ruinous competition. Therefore, in addition to the increase of aggregate demand as illustrated in

MSV, the increase of product differentiation through innovation and research and development (R&D) is also critical in the stimulation of industrialization.

Chapter 3 shifts the view from industrialization in national economies to regional industrial structures. Krugman's new economic geography (NEG) model (1991) made a symmetric assumption on the production of variety goods, and the majority of NEG studies aggregated the production activities (excluding agriculture) into one kind of the variety goods, failing to model the characteristics of different manufacturing activities. They always assumed an exogenous interregional productivity gap, which determines regional comparative advantage and industrial structures, without explaining how the productivity gap was formed. Chapter 3 extends Krugman's original model to a two-industry and two-factor case where the manufacturing activities are classified into intermediate input-intensive（high-tech) industries and labor-intensive (low-tech) industries as done in Matsuyama (1996). It uses local fixed capital stocks to represent the local variety of intermediate inputs, hence connects the local variety of intermediate inputs with the local productivity and enables the endogenous analysis of the regional productivity. Then, it shows that the region with more fixed capital has an absolute advantage in the two manufacturing industries and a comparative advantage in the capital-intensified (high-tech) industry. This leads to such regional manufacturing structures that the capital-abundant region has larger revenues of the two manufacturing industries (reflecting the absolute advantage) and a larger revenue ratio of the high-tech to low-tech industries (reflecting the comparative advantage). These theoretical inferences are supported using evidence from the data on the regional industrial structures in China. So, to upgrade a region's industrial structure, it is important to strengthen the local fixed capital stock so as to attract more and more high-tech industries to agglomerate to the region.

Chapter 4 investigates the industrial upgrading in urban economies by extending Henderson's model (1974) of urban system into a two-industry case of urban system with inter-urban trade to investigate the relationship between urban agglomeration and industrial upgrading. Since the major channels of agglomeration economies are labor pooling, knowledge spillovers, and sharing the specialized local services, urban areas will have comparative advantage and relatively specialize in such production activities that are intensive in skilled labor, scientific research and education, and information and communications. Chapter 4 develops an industrial stage index to reflect industries' input intensities in high-tech activities (skilled labor, scientific research and education and information and communications), and then uses this index with cities' industrial employment composition to form an urban industrial stage index for cities, which reflects their intensities in high-tech activities. The relationship between urban agglomeration (reflected by total employment or employment density) and urban industrial upgrading (reflected by the urban industrial stage index) is verified using city-level panel data from Japan's economic census. The result implies that to keep the industrial upgrading in cities, it is needed to encourage population to agglomerate in large cities and centralize the population.

Chapter 5 concludes this dissertation and suggests some subjects for future research.

In short, this dissertation clarifies the role of product differentiation in the industrialization process in national economies, and analyzes industrial structure and industrial upgrading in regional and urban economies. It illustrates that (a) the increase

of product differentiation stimulates industrialization, (b) the increase of local fixed capital stock raises the level of regional industrial structure, and (c) urban agglomeration is positively associated with urban industrial upgrading.

要旨

本論文は、製品の異質性を考慮し、一国における産業化（原始的な生産方式から工業化された生産方式への転換）、地域と都市経済における産業構造及びその高度化（ローテク産業からハイテク産業への転換）を分析するものである。全文は、次の5章から構成される。

第1章は、中国と日本における産業化、産業構造とその高度化の背景を説明し、産業化、産業構造とその高度化の先行研究をサーベイした。

第２章は、まずMurphyほかのモデル(1989)を示し、その主要な結論を提示した。それは、最初に産業化する部門が正の利潤をもらえば、総需要へのスピルオーバー効果が発生し、産業化過程が自己持続的になることである。しかし、そのモデルは総需要の重要性を明らかにしたが、製品の異質性を捉えなかった。この章ではDixit-Stiglitz(1977)の独占競争の考え方を使い、製品の異質性をモデルに導入した。製品間の代替弾力性が高ければ、産業化した部門が値下げを行い、競争相手の売上高を奪うことが示された。これは「ビジネス盗み効果」と言われている。もしこの「ビジネス盗み効果」が総需要スピルオーバー効果を上回れば、産業化の進展に伴い、産業化部門の利潤が減少に転じる。これにより、指摘されていないいくつかの産業化のパターンを示すことができた。その結果は産業化を促すために、研究開発を通して、製品の差別化と多様化を進めることの重要性を示した。

第３章は、一国の産業化の視点から地域経済の産業構造の視点へ移る。Krugmanの新経済地理（NEG）モデル(1991)では、異質財に対称性の仮定をおいたため、その後の多くのNEG研究は生産活動(農業以外)を一種の多様財の生産に簡略化し、生産活動の異質性を考慮しなかった。一部の研究は地域間の生産

性の違いを外生的に設定したが、その違いの形成要因を分析していない。この章はKrugmanの新経済地理（NEG）モデルを2産業と2生産要素のケースへ拡張した。Matsuyamaのモデル(1996)を参照に、2産業を中間財集約的なハイテク産業と労働力集約的なローテク産業に分けた。また地域の中間財の種類を地域の固定資本総量で表した。それによって、地域の生産性を地域の固定資本総量と関連づけ、地域間の生産性の違いを内生的に分析することができた。その結果、多数の固定資本総量を持つ地域では、2産業についても絶対優位性を持ち、ハイテク産業については比較優位性を持つことを明らかにした。こうして、次のような地域産業構造が示された。多数の固定資本総量を持つ地域は2産業の生産額を多く生産する（絶対優位性のため）。この地域において、ハイテク産業とローテク産業の生産額の比率はより高い（比較優位性のため）。これらの理論結果は、中国の地域産業構造データによって裏付けられる。その政策的な意義としては、地域のハイテク中心の産業構造を実現するために、地域の固定資本の形成を促す必要であることが示唆された。

第４章では、都市レベルの産業構造の高度化を考察するために、Hendersonの都市システムモデル(1974)を2産業で都市間の貿易も存在する都市システムモデルへ拡張した。集積の経済性は主に労働市場の共有,知識スピルオーバー、地域の専門サービスの共有によるため、大都市では熟練労働者、研究開発、専門サービスへの依存度が高いハイテク産業について比較優位性を持ち、ハイテク産業の生産に特化することになる。この理論を検証するために、この章は各産業へのハイテク活動(熟練労働、研究開発、情報通信)の投入状況により、各産業の産業レベル指数を構築した。またこの産業レベル指数と都市の労働力構成をもって、各都市の都市産業レベル指数を構築した。この都市産業レベル指数は各都市におけるハイテク経済活動に従事する労働者の状況を反映し

ている。また日本経済の統計資料から都市のパネルデータを整理し、就業者の集積が(総就業者数と就業者密度で反映)都市の産業構造のレベル（都市産業レベル指数で反映）へ正の影響を与えていることを検証した。この結果によれば、都市の産業構造の高度化を促進するために、人口が大都市へ集積する必要であることが示唆された。また大都市の人口を分散させるような政策はその障害になる可能性がある。

第５章は、論文全体を総括し、今後の研究を指摘した。

要約すると、本論文は製品の異質性が産業化に果たす役割を明らかにし、地域と都市おける産業構造とその高度化のメカニズムを分析し、以下の結論を得た。(a)製品間の代替弾力性が高い場合、産業化の進展に伴う工業化部門の利潤が減少に転じる。従って、産業化を促すために、製品の差別化と多様化を強化する必要である。(b)地域の固定資本の形成は、地域の生産性を高め、ローテク産業からハイテク産業への産業転換を促す。(c)都市への集積は、都市の産業構造とその高度化に寄与する。都市の産業高度化を促進するために、人口が大都市へ集積することが必要である。

Chapter 1 General Introduction

1.1 Industrialization and Industrial Upgrading in Japan and China

Industrialization and industrial upgrading play very important roles in economic growth (Deane, 1979; Schumpeter, 1942).

Deane (1979, p. 1) noted that industrialization has induced leaps in economic growth over the last 200 years. In particular, he indicated:

> "The striking disparity between the standards of living of the inhabitants of the so-called developed or advanced countries of the mid twentieth century and the standards prevailing in today's underdeveloped or backward countries is essentially because the former have industrialized and the latter have not."

Meanwhile, the realization of sustainable economic growth has largely depended on industrial upgrading, as Schumpeter (1942, pp. 82-83) pointed:

> "The essential point to grasp is that in dealing with capitalism we are dealing with an evolutionary process…. The fundamental impulse that sets and keeps the capitalist engine in motion comes from the new consumers' goods, the new forms of industrial organization that capitalist enterprise create."

The two major economies, those of Japan and China, are typical examples that show the roles of industrialization and industrial upgrading in economic growth.

Japan began industrialization between 1878 to 1899, which led to a take-off of economic growth. As a result, the year 1940 was called a "rough symbolic date for technological maturity" for Japan (Rostow, 1960). After World War II, Japan's economic growth in the space-confined, mountainous, and resource-scarce archipelago, which is approximately the size of the state of Montana in the US but with nearly half of America's population, was a story of great industrial upgrading. This upgrading made Japan join the ranks of advanced economies as the world's second largest economy over a short span of time of less than three decades (Ozawa, 2005).

After the founding of the People's Republic of China in 1949, with the Soviet Union's assistance, the Chinese government initiated socialist industrialization and set up the industrialization foundation in the 1978. Since the reform and opening policy adopted at the beginning of the 1980s, industrialization in China accelerated, and meanwhile, the industrial structure was upgraded. One major reason is that the influx of foreign direct investment (FDI) in the coastal region of China (From 1984 to 1994, more than 90% of total FDI inflow went to the coastal region) industrialized the production activities there and upgraded the industrial structure involving many high-tech industries, such as digital wristwatches, recorders, colour TVs, and cameras (See Tables 1, 2, 3 in Chapter 3). With the rapid industrialization and industrial upgrading, the Chinese economy took off.

Although Japan and China both have achieved great successes in industrialization and industrial upgrading, which contributed greatly to their economic take-offs, they are continuing to face new challenges concerning further industrialization and industrial upgrading.

From the beginning of 1990s, Japan's economy has fallen into a long-term stagnation. One major reason is that Japan's economy failed to continue to upgrade its industrial structure. Specifically, During the period between 1995 and 2004, Japan's information and communication technology (ITC) investment ratio in GDP was the lowest among the major developed countries (See Fig 1.1). Fukao et al. (2009) showed that lack of ITC investment was one of the major reasons for the long-term stagnation in Japan.

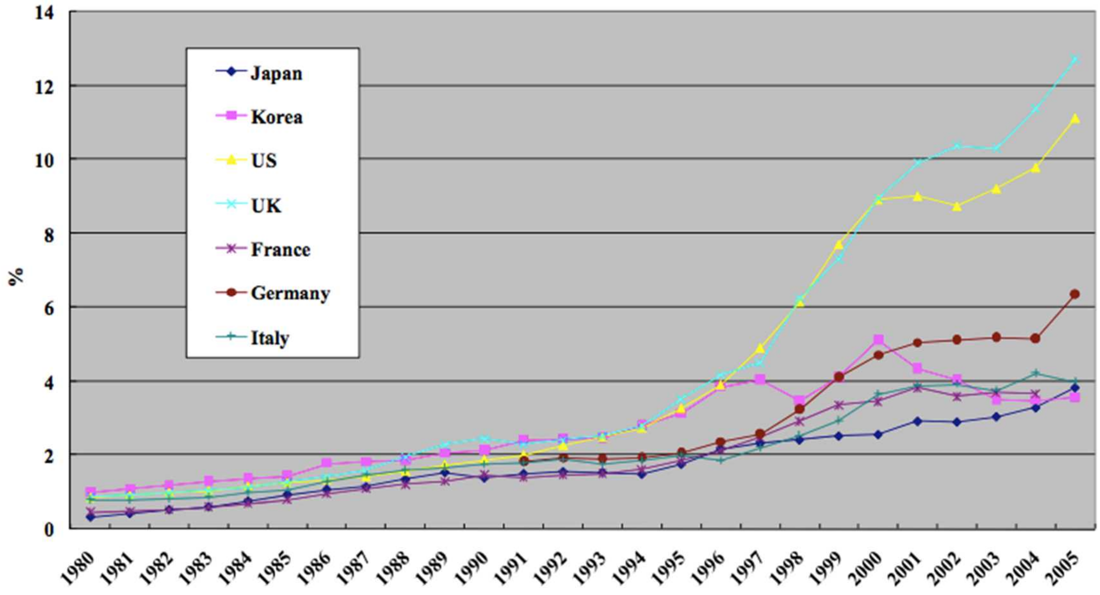

Fig. 1.1 ICT investment/GDP ratio in major developed countries

Data Source: Fukao, Miyagawa, Pyo and Rhee (2009)

To stimulate innovation and the industrial upgrading all over the country, MITI (Ministry of International Trade and Industry of Japan) initiated the so-called technopolis project in 1984 under the "Technopolis Law" of 1983. The technopolis project was designed to establish twenty "technopolises" across Japan's archipelago corridor. Each technopolis was expected to be an integrated complex of high-tech industries, research universities, local supporting industries, housing, and communications and transportation facilities, as well as a high-tech cluster that engenders economies of linkage and agglomeration. In 1986, MITI further initiated the so-called regional research core project to further enhance innovation and the industrial upgrading. However, the two projects failed to create the intended viable research clusters, since business services and amenities were not available in those isolated rural locations chosen by MITI (Ozawa, 2005, pp. 99-101). In this sense, it is necessary to investigate what kinds of regional policy are more appropriate for industrialization and industrial upgrading so as to disperse economic activities as done in the technopolis and regional research core projects or to centralize economic activities.

In the current China, although a wide range of economic sectors have industrialized, the agricultural production remains relatively rudimentary, which leads to lower labor productivity in agriculture sector and larger urban-rural income gap (according to the National Bureau of Statistics, in 2017, the annual per capita income of urban residents is 2.71 times higher than that of rural residents). Gao (2015) pointed out that the labor productivity in agriculture depended on three factors, which were land productivity, the output conversion rate and the land-labor ratio[1]. Wang (2007) illustrated that the investment for the improvement of land productivity was the most effectual way to increase labor productivity, while Han et al. (2007) showed that the increase of output conversion rate, specifically the development of agriculture diversity was critical to promote peasant's economy efficiency.

In a comparative study on 128 countries' (regions') agriculture, in year 2010, the land productivity of China was 5520.6 kilogram (in grain) per hectare, higher than the world average level (3563.54 kilogram), ranked in the sixteenth, while the labor productivity (value added per farmer, in constant prices of the year 2000) was 544.96

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[1] Land productivity represents the output quantity per hectare, output conversion rate represents the quantity value to the monetary value conversion rate, and land-labor ratio represent the agriculture acreage per capita. .

dollar per capita, 0.513 times of the average value of the world, 0.013 times of that of Japan and 0.011 times of that of American, ranked in the 103th (in 128 countries/regions). This implies that the critical factor in the development of agriculture in China is the increase of output conversion rate. Generally, the output conversion rate depends on the agriculture structure and agricultural protection level. The improvement of agriculture structure mainly refers to the transformation from the traditional homogenous grains to the diversified, high value added animal husbandry and cash crops (Gao, 2015). Therefore, the main reason for the low labor productivity in agriculture sector is the homogenous property of agricultural goods, which lowers the output conversion rate (market prices) of agricultural products. With the homogenous property of agriculture goods, the investment for the improvement of land productivity often induces over production and causes great losses. For example, in November, 2015, the farmers in Yangxin (a county in Shandong Province) had a bumper harvest in celery. However, due to the over production, the price of celery fell to 0.30 yuan per kilogram and the farmers lost 2000 to 3000 yuan per acre.

So, to stimulate the industrialization of agriculture, the relationship between product differentiation and industrialization needed to be deeply analysed.

Furthermore, China is confronting an unbalanced regional growth problem. Since the reform and opening policy was adopted, the industrial structure in the coast region has gradually upgraded to involve many high-tech industries, such as electronic, information and communication industries. Meanwhile in the interior region of China, the industrial structure remains dominated by labour-intensive and resource-intensive industries. Considering the critical role of FDI played in the industrial upgrading in the coast region, , it is needed to investigate the relationship between regional fixed capital and the formation of regional industrial structures so as to formulate the proper regional policy that can improve the industrial structure in the interior region

1.2 Review of Related Economic Literature

1.2.1 Regarding Industrialization

In formulating a proper economic policy to stimulate the industrialization of agriculture, which is fettered by homogenous property and scattered small-scale production, it is necessary to determine the relationship between production differentiation and industrialization. The existing literature focuses on the effects of aggregate demand in the industrialization process but fails to analyze product differentiation. Rosenstein-Rodan (1943) indicated that, if various sectors of the economy adopted increasing return technologies simultaneously, they could each create income that becomes a source of demand for goods in other sectors and thus enlarge their markets and make industrialization profitable. As a result, the simultaneous industrialization of many sectors can be profitable for them, even when no sector can break even through industrialization alone. This insight has been modelled by Murphy, Shleifer and Vishny (MSV, 1989). But, to focus on the effect of aggregate demand on industrialization, MSV neglected the analysis of production differentiation and assumed unit-elastic demand instead. This makes their theory inapplicable to explain the industrialization process for the production of homogenous goods such as agriculture.

Murphy et al. (1989) and Shleifer and Vishny (1988) noted that, when demand is elastic, the industrializing firms could reduce prices to steal the sales from other sectors. They wrote (Murphy et al., 1989, footnote 7, p. 1011):

> “All the models we study assume unit-elastic demand. Historically, however, price-elastic demand for manufacturers has played an important role in the growth of industry. Price elastic demand leads to price cuts by a monopolist and an increase in consumer surplus, which is an additional reason for a big push.”

In fact, certain historical evidence has shown that with price-elastic demand, industrializing firms may reduce prices to steal sales from their competitors, thereby creating a negative externality on the demands (profits) of their competitors, which may lead to the so-called ruinous competition (Lamoreaux 1980, Jone 1920).

Lamoreaux (1980) used the concepts of price-cutting and ruinous competition to explain a wave of mergers after a wave of investment in manufacturing during the boom of the late 1880s and early 1890s. Jones (1920) investigated the emergence of ruinous competition and found that homogenous good enterprise are more likely to conduct price-cutting to attract business away from other sectors, which creates negative externalities in industrialization.

However, until now, the microeconomic foundations for the relationship between production differentiation and industrialization have not been built. In this dissertation, Chapter 2 will analyze such a relationship in detail. It will show the importance of product differentiation in stimulating industrialization.

1.2.2 Regarding Regional Industrial Structures

In formulating a proper regional policy to improve the economy of the interior region and realize the balanced economic growth between coast and interior regions in a country, it is necessary to investigate the formation of industrial structures in the regional economies.

Fujita and Hu (2001) empirically investigated the regional manufacturing structure transition in China from 1980 to 1994. They showed that in the 1980s and 1990s, in the east coast of China, many manufacturing plants were built using foreign direct investment (FDI). In that region, the manufacturing structure became characterized by the agglomeration of high-tech industries, which were heavily based on the inputs of intermediate goods or capitals.

However, the mainstream of regional economics has not paid attention to the industrial structure analysis. Krugman's new economic geography (NEG) model (1991) made a symmetric assumption on the production of variety goods, and the majority of NEG studies aggregated the production activities (excluding agriculture) into one kind of variety goods, failing to model the characteristics of different manufacturing activities.

Some studies (Venables, 1999; Amiti, 2005; Tan and Zeng, 2013) assumed an exogenous interregional productivity gap that determine local comparative advantage and industrial structures, without explaining how this productivity gap was formed. Mastuyama (1996) divided the manufacturing activities with IRS (increasing returns to scale) into two industries based on their input intensities: the intermediate input-intensive (high-tech) industry and the labour-intensive commodity industry. He showed that the production costs of the two final products decrease as the variety of intermediate inputs increases (due to increasing returns). Meanwhile, assuming that the high-tech industry uses intermediate inputs more intensely than the commodity industry, he illustrated that the high-tech industry benefits more from increasing returns generated by the variety of intermediate inputs. As a result, a country endowed with a wider variety of intermediate inputs will acquire a comparative advantage in the high-tech industry and will specialize in it.

Moreover, although FDI plays an important role in the formation of regional manufacturing structures, for simplicity, the majority of NEG studies took labor as the only input factor in the production of manufacturing goods. Martin and Rogers (1995) introduced capital as another factor into the NEG model (generally referred to as the footloose capital (FC) model). In the FC model, the local variety of manufacturing activities was represented by the amount of local capital.

In this dissertation, Chapter 3 will rebuild Matsuyama's (1996) model by introducing fixed capital stock to represent the local variety of intermediate inputs. It will connect the local variety of intermediate input with the local productivity, which enables the endogenous analysis of the local productivity. It will answer the following questions. How does the local variety of intermediate inputs (as reflected by the local fixed capital stock) of a region relate to the local manufacturing productivity and the corresponding local comparative advantage? With this local comparative advantage, how are regional manufacturing structures formed, and how is the population distributed across regions?

1.2.3 Regarding Urban Industrial Upgrading

In formulating a proper regional policy that can stimulate the industrial upgrading of a country, it is necessary to understand the mechanism of industrial upgrading in urban areas, which are the engine of the country's economic growth.

Unfortunately, the existing literature on industrial upgrading (Schumpeter, 1942; Aghion and Howitt, 1990; Ozawa, 2005) failed to consider the effects of spatial distribution of economic activities. On the other hand, the mainstream of urban economies has not paid sufficient attention to the industrial upgrading analysis. The model of urban system (Henderson, 1974) appears to be ill-suited to explain the mechanism of urban industrial upgrading because it assumed that a firm enjoys positive externalities from the intra-industry spatial concentration of economic activities only. As the result, a city only specializes in one industry. As Abdel-Rahman and Anas (2004, p. 2313) noted:

> "If a city contains only one industry, it is referred to as a specialized city; if it contains all of the modeled industries (or at least more than one), it is called a diversified city. All models of a city system have either specialized or diversified citie…Are cities in the system identical in size and in industrial composition or are they different?"

That is, the existing models of urban system lack the analysis of the specific industrial compositions of cities.

The study by Davis and Dingel (2014) is an exception, as it developed a multi-sector urban system model linking urban sectoral composition to city size and skill composition. In their model, all sectors of a city are assumed to be equally affected by common city-dependent agglomeration economies. Different from this, many empirical studies have confirmed that high-tech industries benefit more from agglomeration economies (Henderson et al., 1995; Duranton and Puga, 2001; Rosenthal and Strange, 2003). In this dissertation, Chapter 4 will introduce the industry-specific agglomeration economies into the classical model of urban system (Henderson, 1974) and show that the cities with more total employment will have comparative advantages and specialize in the production of high-tech goods. It will theoretically and empirically analyze the relationship between urban agglomeration and industrial upgrading.

1.3 The Purpose and Organization of this Dissertation

Based on the above discussion, we can say that Japan and China are facing urgent issues regarding industrialization and industrial upgrading. Japan needs to formulate proper regional policies that can stimulate industrial upgrading to recover the country's economy, while China needs to further industrialize its agriculture production and improve the industrial structures of its interior and coastal regions. At the present, the existing economic literature has not provided satisfactory answers to such issues.

Specifically, concerning the relationship between industrialization and production substitutability, although the MSV model showed the role of aggregate demand in the industrialization process, it lacked the analysis of production differentiation. Concerning the formation of regional industrial structures, Krugman's new economic geography (NEG) model made a symmetric assumption on the production of variety goods (Dixit and Stiglitz, 1977), and the majority of NEG studies aggregated the production activities (excluding agriculture) into one set of the variety goods, failing to model the characteristics of different manufacturing activities. Although there are few exceptions that assumed an exogenous interregional productivity gap, which determines regional comparative advantage and industrial structures, they have not explained how the productivity gap was formed. Concerning the industrial upgrading, the existing literature failed to consider the effects of the spatial distribution of economic activities, while the mainstream of urban economies has not paid attention to the industrial upgrading analysis.

In this consideration, this dissertation's purpose is to investigate the industrialization process with production differentiation in national economies, the formation of industrial structures in regional economies and the industrial upgrading in urban economies. The organization of this dissertation is as follows.

Chapter 2 will briefly review the MSV model and then introduce the production differentiation analysis into it using the Dixit-Stiglitz monopolistic competition framework. It will show that, with high production substitutability, industrializing sectors will reduce their prices and steal sales from their competitors, leading to a business-stealing effect. Moreover, it will illustrate that if this business-stealing effect dominates the MSV aggregate demand spillovers, the profits of industrializing monopolists will decline with the industrialization level, and the industrialization process will no longer be self-sustaining. This means that there will be two industrialization patterns: partial industrialization and ruinous competition, which are neglected in the existing literature. That is, in addition to the increase in aggregate demand as illustrated in the MSV model, the increase of production differentiation is also critical in the stimulation of the industrialization process.

Chapter 3 will extend Krugman's original model into a two-industry and two-factor case, where the manufacturing activities are classified into intermediate input-intensive (high-tech) industries and labour-intensive (low-tech) industries, as done in Matsuyama (1996). It will use local fixed capital stocks to represent the local variety of intermediate inputs and hence connect the local variety of intermediate input with the local productivity, which enables the endogenous analysis of local productivity. Then, it will show that the region with more fixed capital has an absolute advantage in both the high- and low-tech manufacturing industries and a comparative advantage in the capital-intensified (high-tech) industry. This advantage leads to such regional manufacturing structures that the capital-abundant region has larger revenues of the two industries (reflecting the absolute advantage) and has larger revenue ratio of the high-tech to low-tech industries (reflecting the comparative advantage). It will also use data on China's regional manufacturing industries to empirically support these theoretical inferences.

Chapter 4 will extend Henderson's urban system model (1974) into a two-industry urban system model with inter-city trade to investigate the relationship between urban agglomeration and industrial upgrading. Since the major channels of agglomeration economies are labour pooling, knowledge spillovers, and sharing the specialized local services, urban agglomerations will bring about comparative advantage and specialize in the production activities which are intensive in skilled labour, scientific research and education, and information and communications. This chapter will develop an industrial stage index, which reflects the industry's input intensities in high-tech activities (skilled labour, scientific research and education, and information and communications), and then use this industrial stage index and urban industrial employment composition to build an urban industrial stage index for cities; which reflects cities' proportion of employment in high-tech activities. The association between urban agglomeration (reflected by total employment or employment density) and industrial upgrading (reflected by the urban industrial stage index) will be verified using city-level panel data collected from the Japanese economic census.

Finally, Chapter 5 will conclude this dissertation, discuss its contribution and policy implications, and indicate several subjects for future research.

Chapter 2 Product Substitutability and Industrialization Patterns

2.1 Introduction

In studying the problem of industrialization, Rosenstein-Rodan (1943) indicated that if various sectors of the economy adopted increasing return technologies simultaneously, they could each create income that becomes a source of demand for goods in other sectors and thus enlarge their markets and make industrialization profitable. Therefore, the simultaneous industrialization of many sectors can be profitable for them even when no sector can break even industrializing alone.

This insight has been developed by Murphy, Shleifer and Vishny (MSV 1989), which defined such industrialization process as the “big push”. They made two major contributions. First, they showed that if a firm contributes to the demand for other firms' goods *only* by distributing its profits and raising aggregate income, then unprofitable investments will reduce income and, therefore, the size of other firms' markets. Consequently, when profits are the only channel for spillovers, the industrializing equilibrium cannot coexist with the unindustrializing one. Second, they modeled three types of externalities generated from industrialization in which a firm's profit is not an adequate measure of its contribution to the profits of manufacturers, and both equilibriums (industrialization and unindustrialization) could coexist. These are, (i) a firm that sets up a factory pays a wage premium; so it increases the size of the market for producers of other manufacturers, even if its investment loses money. (ii) A firm that uses resources to invest at one point in time but generates the labor savings from this investment at a later point decreases aggregate demand today and raises it tomorrow. (iii) When many sectors pay for railroads, and railroads decrease effective production costs, an industrializing sector has the effect of reducing the total production costs of the other sectors. In (i) and (ii), the possibility of the big push turns on the divergence between a firm's profits and its contribution to the demand for manufacturers of other investing firms. In (iii), the possibility of the big push hinges on sharing in infrastructure investments.

To focus on the mechanism of the big push, MSV only considered these positive externalities in industrialization. Nevertheless, some historical evidence suggests that industrializing firms may cut prices to steal sales from their competitors, thereby creating a negative externality on the demands (profits) of their competitors, which may lead to ruinous competition (Lamoreaux, 1980; Jone, 1920).

Lamoreaux (1980) used the concepts of price-cutting and ruinous competition to explain a wave of mergers after a wave of investment in manufacturing during the boom of the late 1880s and early 1890s. The improvements in transport and communications made the investment in mass production become profitable and triggered simultaneous industrialization across various sectors, which created overexpansion in industries characterized by high fixed costs. When the problem of excess capacity arose, the industrializing producers set off a bout of retaliatory price cutting to increase market shares at the expense of others. Profits were reduced to ruinously low levels, and this predicament spurred manufacturers to form oligopolistic market structures (through consolidation) to maintain prices.

Jones (1920) investigated the emergence of ruinous competition[2]. He summarized seven characteristics of industrial enterprises associated with ruinous competition, which include "large fixed expenses (pp. 488-490)", "price-elastic demand (p. 494)" and "a high likelihood of price-cutting (pp. 494-496)". In "a high likelihood of price-cutting", he noted that compared with *differentiated* goods enterprises[3], *homogenous* goods enterprises are more likely to conduct price-cutting to *attract the business away* from other sectors, which creates negative externalities in industrialization.

In fact, the possible price-cutting strategies of industrializing monopolists have also been noticed by MSV (Murphy et al., 1989, footnote 7, p. 1011):

> "All the models we study assume unit-elastic demand. Historically, however, price-elastic demand for manufacturers has played an important role in the growth of industry. Price elastic demand leads to price cuts by a monopolist and an increase in consumer surplus, which is an additional reason for a big push."

In a related paper, Shleifer and Vishny (1988, p.1225) also noted that when demand is sufficiently inelastic, a cost-reducing firm will refrain from price-cutting, and when demand is elastic, the industrializing firms could cut prices to steal the sales from other sectors.

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[2] In Jones (1920), the ruinous competition of a railroad was defined as "competition among railroads, unless restrained, tends to become 'ruinous,' that is, fails to establish a normal level of rates sufficiently remunerative to attract the additional investments of capital that recurrently become necessary." Also, Knauth (1916, p. 245) defined ruinous competition as "that which forces prices to a point where the capital invested receives no return, and even fails to maintain its value intact."

[3] Jones (1920, p. 494) classified the goods with a marked development of brands and trademarks, the goods wherever competition is on a quality or style basis, e.g., tobacco, sugar, harvester, gunpowder, whisky, starch, bicycle, silverware, and aluminum ware businesses, into the category of differentiated goods, and staples into the category of homogenous goods.

Although MSV noticed these possible negative externalities brought about by price-cutting strategies, they failed to analyze them in their models due to their *unit-elasticity assumption*.

The above discussions concerning negative externalities in industrialization suggest the following possibility. With high product substitutability, demand becomes inelastic, so a cost-reducing (industrializing) firm could maintain its price. When product substitutability is low, demands will change dramatically with price-cutting, so a cost-reducing firm will be more likely to cut price to steal the sales from others, which creates negative externality and probably leads to ruinous competition. However, to our knowledge, the microeconomic foundation of such possibility has not been established. So, in this paper we aim to expound the mechanism underlying product substitutability, price-cutting strategy and industrialization.

In the mechanism, the price-cutting strategies and the associated negative externality hinge on product substitutability. Product substitutability measures how differentiated products are substitutable for each other. There are two frequently used measures of such substitutability. (i) The price elasticity of demand is generally defined as the percentage change in quantity demanded divided by the percentage change in price, and a large price elasticity of demand implies large substitutability across differentiated products. The price elasticity of demand also reflects a producer's monopoly power (Lerner, 1934). (ii) The elasticity of substitution is generally defined as the percentage change of the demand ratio divided by the percentage change of the price ratio between two differentiated products, and a large price elasticity of demand implies a large substitutability across differentiated products. In the Dixit and Stiglitz

(D-S) model[4], both the price elasticity of demand and the elasticity of substitution are invariant with price changes (constant elasticity of substitutability, CES afterwards) and are equal to each other.

To analyze the role of product substitutability in the industrialization process, we introduce the D-S monopolistic competition model, where the monopolist optimizing prices hinge on substitutability, into the simplest model in MSV,[5] where an industrializing firm contributes to the demand for other firms' products *only* by distributing its profits and raising aggregate income. Specifically, after presenting the basic model of MSV in Section 2.2, in Section 2.3, the D-S monopolistic competition model is introduced into it to illustrate how product substitutability determines monopoly pricing strategies. Section 2.4 unveils the following industrialization possibilities and clarifies the role of product substitutability. (a) When substitutability is low, even if industrializing firms achieve higher productivity, they will not cut their monopolistic prices to steal the sales from others, and the industrialization process will be self-sustaining. (b) When substitutability is high, industrializing firms will cut prices to steal the sales from their competitors, leading to a business-stealing effect. Regarding this effect, if aggregate demand spillovers dominate it, the profit of industrialization will *rise* with the industrialization level, and the industrialization process will be *self-sustaining*. Conversely, if the business-stealing effect dominates aggregate demand spillovers, the profits of industrializing firms will *decline* with the progress of industrialization. These two possibilities suggest the following four potential industrialization patterns. (i) *Complete industrialization*: the profits remain positive

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[4] See Dixit and Stiglitz (1977).

[5] It is the model outlined in Murphy et al. (1989), Section III.

until all sectors industrialize. (ii) *Unindustrialization*: the profits are negative at the beginning of the industrialization process. (iii) *Partial industrialization*: the first industrializing firm has a positive profit, and the industrialization process stops when the profit of industrialization becomes zero. (iv) *Ruinous competition*: if the profits of industrialization are positive at the beginning and turn negative when all producers industrialize, and the producers are all myopic (they only consider their own short-term profits), so they will simultaneously industrialize at the beginning and end up with negative profits.

2.2 The Basic Model of MSV

In this section, we present the basic industrialization model of MSV[6] to show that if profits are the only channel of spillovers, the industrialization process will be *self-sustaining* (i.e., once the first industrializing firm has a positive profit, the profits of industrialization will increase as the industrialization progress). For this purpose, we use many original expressions used in the basic model.

Suppose that a one-period economy has a representative consumer who has the following Cobb-Douglas utility function defined over a unit interval of goods ($x_{(q)}$) indexed by q, $q \in [0,1]$.

$$U = \int_0^1 lnx_{(q)}dq \qquad (2.1)$$

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[6] See Murphy et al. (1989), Section III, pp.1007-1010.

Equation (2.1) implies that all goods have the same expenditure shares. Thus, when the representative consumer's income is denoted as Y, he can be thought of as spending Y on every good $x_{(q)}$.[7] The consumer is endowed with L units of labor, which he supplies in an inelastic way, and he owns all the profits of the economy. If his wage is taken as the *numeraire*, his budget constraint is given by:

$$Y = \Pi + L \qquad (2.2)$$

where Π is the aggregate profits, and Y is the aggregate income (or aggregate demand).

Each good is produced in its own sector, and each sector consists of the following two types of firms. First, each sector has a competitive fringe of firms that convert one unit of labor input into one unit of output with constant returns to scale (or, the cottage production) technology. Second, each sector also has a special firm with access to increasing return (or, the industrializing production) technology. This firm is alone in having access to that technology in its sector and thus will be referred to as a monopolist. Industrialization requires the input of F units of labor and allows for each additional unit of labor to produce $\frac{1}{C^I}(> 1)$ units of goods for consumption. C^I is a constant parameter, which represents the reciprocal of marginal productivity of labor; thus, a smaller C^I implies a higher productivity of industrializing production.

The monopolist in each sector decides whether to industrialize or not. The monopolist can maximize his profit by taking the demand curve as given. And, he industrializes only if he can earn a profit at the price he charges. That price equals *one*

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[7] The Cobb-Douglas utility function implies that the representative consumer expend equally on every good. Denote the expenditure as y; we have $Y = \int_0^1 lny \, dq = 1y - 0y = y$.

since the monopolist loses all his available profit to the fringe if he charges more, and he would not want to charge less since he is facing a *unit-elastic demand curve*. When income is Y, the profit of a monopolist who spends F units of labor to industrialize is given by:

$$\pi = (1 - C^I)Y - F \tag{2.3}$$

When a fraction n of the sectors in the economy have industrialized, the aggregate profit becomes:

$$\Pi_{(n)} = \int_0^n \left[(1 - C^I)Y_{(n)} - F\right] dq = n[(1 - C^I)Y_{(n)} - F)] \tag{2.4}$$

By substituting Equation (2.4) into Equation (2.2), aggregate income can be expressed as a function of the industrialization level n:

$$Y_{(n)} = \frac{L - nF}{1 - n(1 - C^I)} \tag{2.5}$$

As MSV indicated, the numerator of (2.5) is the amount of labor used in the economy for the actual production of output after investment outlays. One over the denominator is the multiplier showing that an increase in effective labor raises income by more than one since the expansion of low-cost sectors also raises profits. To show how the progress of industrialization can contribute to aggregate demand, one can differentiate aggregate demand with respect to n:

$$\frac{dY_{(n)}}{dn} = \frac{\pi_{(n)}}{1-n(1-C^I)} \qquad (2.6)$$

where $\pi_{(n)}$ is the profit of a monopolist when a fraction *n* of the sectors in the economy have industrialized. Equation (2.6) implies that an industrializing firm earns a positive profit when a fraction *n* of the sectors in the economy have industrialized ($\pi_{(n)} > 0$), and it distributes the profit to shareholders, who in turn spend it on products of a whole series of production sectors (i.e., if $\pi_{(n)} > 0, then \frac{\partial Y_{(n)}}{\partial n} > 0$) and thus raise profits in all industrialized firms in the economy. The effect of this firm's profit is therefore enhanced by the increase in profits of all industrializing firms, resulting from increased spending.[8]

Due to the *aggregate demand spillovers,* if the industrialization process begins (i.e., the first industrializing firm makes a positive profit), it will be *self-sustaining*, i.e., the profits of industrialization increase as the industrialization progresses. To see this, from (2.3) one can have:

$$\frac{d\pi_{(n)}}{dn} = (1 - C^I)\frac{dY_{(n)}}{dn} \qquad (2.7)$$

Equation (2.6) shows that if $\pi_{(n)} > 0$, then $\frac{dY_{(n)}}{dn} > 0$[9], and equation (2.7) means that if $\frac{dY_{(n)}}{dn} > 0$, then $\frac{d\pi_{(n)}}{dn}$>0[10]. So, if $\pi_{(n)} > 0, then$ $\frac{dY_{(n)}}{dn}$>0, and then $\frac{d\pi_{(n)}}{dn}$>0. That is, if it is

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[8] Similar descriptions of aggregate demand spillovers can be found in Murphy and Vishny (1988, pp.1224-1225) and Matsuyama (1992, p. 354).

[9] Since in equation (2.7), $1 - n(1 - C^I) > 0$.

[10] Since in equation (2.6), $1 - C^I$>0.

profitable for one monopolist to invest in industrialization, it will be more profitable for additional monopolists to do so due to the aggregate demand spillovers.

2.3 Monopolistic Competition and Pricing Strategies

In this section, the D-S monopolistic competition framework, where the monopolist-optimizing prices depend on product substitutability, is introduced into the basic model of MSV to show how pricing strategies of industrializing firms depend on substitutability. That is, (a) with low substitutability, the monopolists will refrain from price-cutting, and, (b) with high substitutability, they will conduct price-cutting.

Similar to the MSV basic model, a one-period economy with a representative consumer is considered. However, we assume that the consumer has a more general D-S type of CES utility function[11] over a unit interval of goods, indexed by *i,* $i \in [0,1]$, as follows[12]:

$$U = [\int_0^1 x_{(i)}{}^{\rho}\ di]^{1/\rho} \qquad 0<\rho<1 \qquad (2.8)$$

where [0,1] is the range of varieties produced, and $x_{(i)}$ denotes the consumption of each available variety. Define $\sigma = 1/(1-\rho)$, which represents the price elasticity of

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[11] In Dixit and Stiglitz (1977), there are two groups or sectors or industries, one of which is composed of varieties, and the other of which represents the rest of the economy, consisting of homogenous goods. Adding another homogenous goods industry will not change the main result.

[12] Consider the economy is within a certain product range (One can add the other production ranges by first defining a whole Cobb-Douglas utility function and a CES sub-utility function. It will not change the core results of the Chapter), then Mrs. Robinson's concept of sector is appropriate here: the products of different firms consist of a "chain of substitutes" surrounded on each side by a "marked gap" within which the demand for the product of each firm is equally sensitive to the price of any of the others (Joan Robinson, 1933).

demand or the elasticity of substitution between any pair of varieties. Concerning σ and ρ, five points are noteworthy as follows. (i) $\frac{d\sigma}{d\rho} > 0$. (ii) When ρ is closer to 1, σ approaches infinity, which implies a large demand elasticity, and the differentiated goods are nearly perfect substitutes for each other (high substitutability). (iii) When ρ is closer to 0, σ approaches 1, which means that the demand for each variety is inelastic, and the desire to consume greater variety of goods is high (low substitutability). (iv) If $\rho = 1$, Equation (2.8) becomes the Cobb-Douglas utility function as defined in Equation (2.1). And, (v) $0<\rho<1$ means that the varieties are substitutes for each other.

Given income *Y* and a set of prices $p_{(i)}$, i$\in [0,1]$, the consumer's problem is to maximize his utility under the budget constraint, which can be expressed as followings:

$$\text{Max } U=\left[\int_0^1 x_{(i)}{}^{\rho}\ di\right]^{\frac{1}{\rho}}$$

$$\text{s.t. } \int_0^1 p_{(i)}x_{(i)}di = Y \tag{2.9}$$

When a fraction *n* of the sectors in the economy industrialize, the solution of this problem yields the following compensated demand function for the *i*th variety of goods:

$$x_{(i)} = p_{(i)}{}^{-\sigma}Y_{(n)}G_{(n)}{}^{\sigma-1} \tag{2.10}$$

$G_{(n)}$ is frequently called the “price index”,[13] which consists of the prices of all differentiated goods and represents the real price of the differentiated goods as a whole. Its expression is:

$$G_{(n)}=\left[\int_0^1 p_{(i)}{}^{1-\sigma}\ di\right]^{\frac{1}{1-\sigma}} \qquad (2.11)$$

Similar to the MSV basic model, the representative consumer is endowed with *L* units of labor, which he supplies in an inelastic way, and he owns all the profits of the economy. If his wage is taken as the numeraire, his budget constraint is given by:

$$Y_{(n)} = L + n\pi_{(n)} \qquad (2.12)$$

where $\pi_{(n)}$ is the profit of an industrializing firm when a fraction *n* of the sectors in the economy have industrialized.

Similar to the basic model, each good is produced in its own sector, and each sector consists of two types of firms. Setting the monopolistic price as p^I, the profit of a monopolist who spends *F* units of labor to industrialize can be written as follows:

$$\pi_{(n)} = (p^I - C^I)x_{(n)}{}^I - F \qquad (2.13)$$

where $x_{(n)}{}^I$ denotes the output (or demand) of each industrializing sector when a fraction *n* of the sectors in the economy have industrialized.

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[13] The expression is borrowed from Krugman (1991, p.492) and Fujita, Krugman, and Venables (1999, p. 47).

Taking the price index G as given and perceiving the price elasticity of demand to be σ, the monopolists prefer to set the monopolistic price as:

$$p^{I'} = C^I/\rho \tag{2.14}$$

where $p^{I'}$ represents the *preferred* monopolistic price. However, as discussed before[14], the range of prices that the monopolist can set is *bounded above by one* (the price set by cottage firms), so, the pricing strategies for the monopolists to take must be as follows: *if* $C^I/\rho \geq 1$*, then* $p^I = 1$*; if* $C^I/\rho < 1$*, then* $p^I = C^I/\rho$, where p^I is the *final* (or realized) monopolistic price set by each monopolist.

It is worth noting that product substitutability now plays an important role in the determination of monopolistic price: if ρ is relatively larger than C^I (i.e., there is high substitutability), monopolists will cut prices; if ρ is relatively smaller than C^I (i.e., there is low substitutability), monopolists will maintain the prices. Note that the price-cutting strategy attracts more demand in the case of high substitutability than that in the case of low substitutability. So, when products have high substitutability, the monopolists are more likely to cut their prices to steal sales from others. This corresponds with the following conjecture in Murphy et al. (1989, p. 1011, footnote 7):

> "Price-elastic demand leads to price cuts by a monopolist".

All the models outlined in MSV are under the unit-elasticity assumption, i.e., ρ equals 0; therefore, in their study, only the case "$C^I/\rho \geq 1,\ p^I = 1$" can exist, i.e., monopolists will always refrain from price-cutting. Taking product substitutability into consideration enables the discussion of the following two cases, Case (I) $C^I/\rho \geq$

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[14] See the discussion before Equation (2.3).

$1, p^I = 1$ (low substitutability) and Case (II) $C^I/\rho < 1$, $p^I = C^I/\rho$ (high substitutability), which will be done in the next section.

2.4 Substitutability and Industrialization

This section investigates the industrialization process and shows that in the case of low substitutability, industrializing firms will not cut prices, and the industrialization process will be similar to that discussed in MSV, and in the case of high substitutability, industrializing firms will cut prices to steal business sales from the others, leading to the so-called business-stealing effect. Moreover, regarding this effect, it will be shown that if it is dominated by aggregate demand spillovers, the profit of industrialization will increase with the industrialization level, and the industrialization process will be self-sustaining. Conversely, if the business-stealing effect dominates aggregate demand spillovers, the profits of industrializing firms will decline with the progress of industrialization.

These two additional possibilities in the profits of industrialization suggest the following four possible industrialization patterns. (i) *Complete industrialization*: the profits remain positive until all sectors industrialize. (ii) *Unindustrialization*: the profits are negative at the beginning of industrialization process. (iii) *Partial industrialization*: the profits are positive at the beginning and the industrialization process stops when the profits become zero. And, (iv) Ruinous competition: the profits are positive at the beginning of industrialization but become negative after the simultaneous industrialization of all sectors.

By taking product substitutability into consideration, we can illustrate that the conditions for individually profitable investment to raise the profitability of investment in other sectors are more stringent than those expressed in MSV. That is, aggregate demand spillovers should be large enough to dominate the business-stealing effect. Such kind of consideration also unveils two possible industrialization patterns, partial industrialization and ruinous completion, which are neglected in MSV.

In the following, we begin to examine the industrialization process with the case of low substitutability.

2.4.1 Case (I) $C^I/\rho \geq 1,\ p^I = 1$ (low substitutability)

In this case, as discussed above before, both the industrializing and cottage firms set the price to one; so the business-stealing effect does not exist, and the industrialization process is similar to that indicated in MSV, which could be expressed by the following proposition.

Proposition 1 *When product substitutability is low (i.e., $C^I/\rho \geq 1$), industrializing firms will not cut prices, so the business-stealing effect will not exist. As long as the first industrializing firm has a positive profit, the industrialization process will be self-sustaining.*

To further examine this proposition, we can substitute $p_{(i)} = 1$ into Equation (2.11) and obtain:

$$\mathrm{G} = 1 \tag{2.15}$$

which means that the price index does not depend on the industrialization level (n), so the business-stealing effect will not occur.

By substituting $p_{(i)} = 1$ and $\mathrm{G} = 1$ into Equation (2.10), the demand for the *i*th variety of goods becomes:

$$x_{(n)} = Y_{(n)} \tag{2.16}$$

Regarding the profit of the first industrializing firm, one can substitute $x_{(0)} = Y_{(0)}$ and $Y_{(0)} = L$ into equation (2.13) and obtain[15]:

$$\pi_{(0)} = (1 - C^{I})L - F \tag{2.17}$$

Due to the existence of aggregate demand spillovers, [16] the condition of self-sustaining industrialization is $\pi_{(0)} > 0$, i.e.,

$$(1 - C^{I})L - F > 0 \tag{2.18}$$

Equation (2.18) illustrates the necessary condition for the patterns of complete industrialization indicated. If $(1 - C^{I})L - F \leq 0$, industrialization will not happen or continue, which means the unidustrialzation pattern. Through investigation about the relations between $\pi_{(n)}$ and n for these two patterns, we can show their industrialization processes in Fig. 1.

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[15] Substituting $n = 0$ into Equation (2.12) yields $Y_{(0)} = L$.

[16] See the discussion following Equation (2.7).

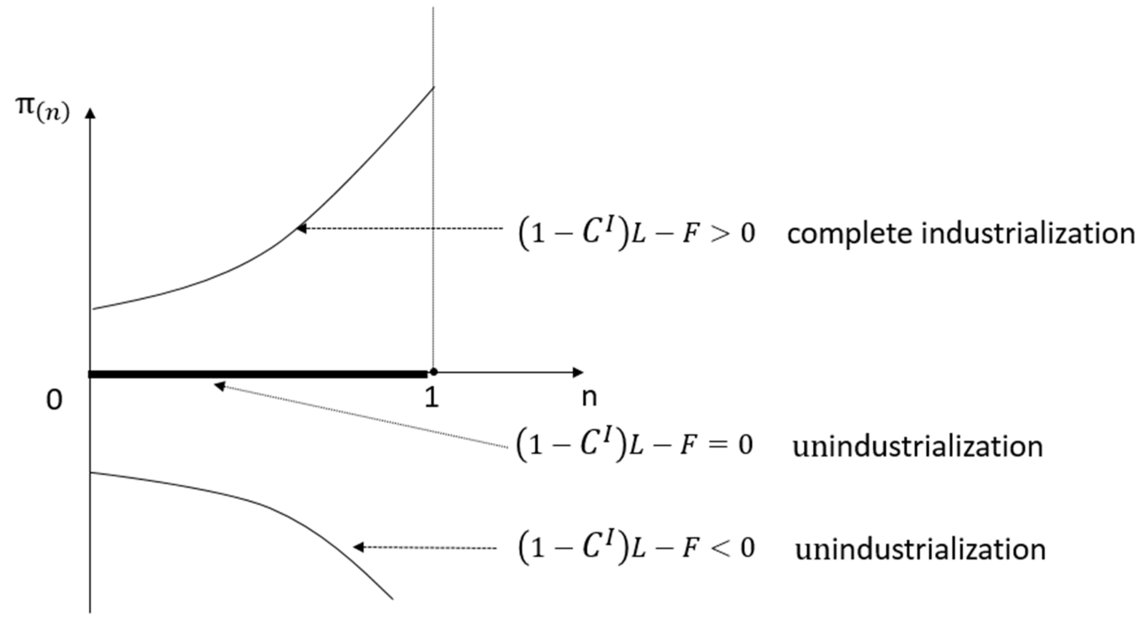

Fig. 2.1 Industrialization process for Case (I)

Note that $\frac{d[(1-C^I)L-F]}{dL} > 0$, $\frac{d[(1-C^I)L-F]}{dC^I} < 0$, and $\frac{d[(1-C^I)L-F]}{dF} < 0$. We can conclude that in the case of low substitutability, a large market, high productivity of industrializing production,[17] and small investment cost of industrialization will contribute to the self-sustaining industrialization.

2.4.2 Case (II) $C^I/\rho < 1,\ p^I = C^I/\rho$ (high substitutability)

When product substitutability is relatively high (i.e., $C^I/\rho < 1$), monopolists will cut prices to steal business away from other sectors (i.e., $p^I = C^I/\rho < \mathbf{1}$).

In this case, by using Equation (2.11), when a fraction *n* of the firms in the economy industrialize, the price index $G_{(n)}$ becomes:

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[17] Note that C^I is the constant marginal input of labor to produce one additional unit of output. So, smaller C^I means higher productivity of industrialization production.

$$G_{(n)} = \{[(\frac{C^I}{\rho})^{1-\sigma} - 1]n + 1\}^{\frac{1}{1-\sigma}} \tag{2.19}$$

Comparing Equations (2.19) with (2.15), we can see that in the case of with high substitutability, the industrialization level (*n*) affects the price index, which implies that the business-stealing effect occurs. This can be confirmed by differentiating the price index $G_{(n)}$ with respect to *n*, which yields:

$$\frac{dG_{(n)}}{dn} = \frac{1}{1-\sigma}[(\frac{C^I}{\rho})^{1-\sigma} - 1]\{[(\frac{C^I}{\rho})^{1-\sigma} - 1]n + 1\}^{\frac{\sigma}{1-\sigma}} < 0 \tag{2.20}$$

and by differentiating the demand function (Equation (2.10)) with respect to $G_{(n)}$, which yields:

$$\frac{dx_{(i)}}{dG_{(n)}} = (\sigma - 1)(\frac{C^I}{\rho})^{-\sigma} Y_{(n)} {G_{(n)}}^{\sigma-2} > 0 \tag{2.21}$$

Equations (2.20) and (2.21) present the mechanism of the business-stealing effect. That is, with weak monopoly power relative to product substitutability, an industrializing monopolist will cut its price ($p^I = C^I/\rho < 1$) to raise the demand for its product (since $\frac{dx_{(i)}}{dp_{(i)}} > 0$). This price-cutting strategy then lowers the price index (since $\frac{dG_{(n)}}{dn} < 0$) and enables monopolist to steal demand from others (since $\frac{dx_{(j)}}{dG_{(n)}} > 0, for\ j \neq i$). So, we obtain the following proposition:

Proposition 2 *With high substitutability (i.e., $C^I/\rho < 1$), industrializing monopolists will cut prices to steal business away from others, leading to the business-stealing effect.*

Substituting the monopolistic price $p^I = C^I/\rho$ and the price index of (2.19) into Equation (2.10) yields:

$$x_{(n)}{}^I = \frac{Y_{(n)}(\frac{C^I}{\rho})^{-\sigma}}{[(\frac{C^I}{\rho})^{1-\sigma}-1]n+1} \tag{2.22}$$

where $Y_{(n)}$ in the numerator represents the aggregate demand spillovers, and *n* in the denominator reflects the business-stealing effect[18]. The comparison between the demand equations of the two cases (i.e., Equations (2.22) and (2.16)) suggests that aggregate demand spillovers exist in both cases, while the business-stealing effect appears *only* in the case of high substitutability.

Next, by substituting Equations (2.12), (2.14) and (2.22) into Equation (2.13), the profit of an industrializing firm when a fraction *n* of the sectors in the economy industrialize becomes:

$$\pi_{(n)} = \frac{(1-\rho)(\frac{C^I}{\rho})^{1-\sigma}L-F\{[(\frac{C^I}{\rho})^{1-\sigma}-1]n+1\}}{[\rho(\frac{C^I}{\rho})^{1-\sigma}-1]n+1} \tag{2.23}$$

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[18] The denominator increases with *n* since $[(\left(\frac{C^I}{\rho}\right)^{1-\sigma} - 1\Big] > 0$.

To see how this profit changes with the progress of industrialization, we can differentiate it with respect to *n*, and obtain the following expression:

$$\frac{d\pi_{(n)}}{dn} = \frac{[1-\rho(\frac{C^I}{\rho})^{1-\sigma}]}{[\rho(\frac{C^I}{\rho})^{1-\sigma}-1]n+1}\pi_{(n)} - \frac{F[(\frac{C^I}{\rho})^{1-\sigma}-1]}{[\rho(\frac{C^I}{\rho})^{1-\sigma}-1]n+1} \qquad (2.24)$$

Equation (2.23) and differential equation (2.24) determine the main characteristics of the industrialization process of Case (II). Some mathematical analyses about (2.23) and (2.24), which are given in the Appendix, yield the following proposition.

Proposition 3 *If* $F < [1-\rho(\frac{C^I}{\rho})^{1-\sigma}]L$, *the profits of industrialization will rise with the progress of industrialization, so the industrialization process will be self-sustaining. If* $F = [1-\rho(\frac{C^I}{\rho})^{1-\sigma}]L$, *the profits of industrialization will be a constant during the progress of industrialization. And, if* $F > [1-\rho(\frac{C^I}{\rho})^{1-\sigma}]L$, *the profits of industrialization will decline with the progress of industrialization.*

Given that positive profits can be expected, the monopolists will industrialize, and given that profits change *monotonically with the progress of industrialization* (except for the constant profit)[19], we can naturally deduce the following four possible industrialization patterns. (i) When $\pi_{(0)} > 0$ and $\pi_{(1)} > 0$, all sectors will industrialize since the industrialization profits continue to be positive until the last sector industrializes, which can be called as *complete industrialization;* (ii) When $\pi_{(0)} < 0$,

---

[19] See the analysis in the Appendix, Lemma 4.

the industrialization process will not start since the first industrializing firm makes a negative profit, and the profits of industrialization will only decline with the progress of industrialization. So, we call this as unindustrialization. (iii) When $\pi_{(0)} > 0$ and $\pi_{(1)} < 0$, the industrialization process could start but will stop when the profit of industrialization becomes zero, which can be named as *partial industrialization*. (iv) When $\pi_{(0)} > 0$, $\pi_{(1)} < 0$ and the producers are supposed to be all myopic (i.e., they only consider their own short-term profits), they may simultaneously industrialize at the beginning and end up if profits become negative, which lead to the so-called *ruinous competition*.

Concluding the two cases on low and high substitutabilities discussed so far, we can obtain the following Proposition 4. More detailed mathematical analyses can be found in the Appendix.

Proposition 4 *If* $F < (1-\rho)L$*, all sectors will industrialize (pattern (i) complete industrialization). If* $(1-\rho)L < F < (1-\rho)\left(\frac{C^I}{\rho}\right)^{1-\sigma} L$ *and a full-information economy is supposed, the industrialization process will stop half way when the profits of industrialization fall to zero (pattern (iii): partial industrialization). If* $(1-\rho)L < F < (1-\rho)\left(\frac{C^I}{\rho}\right)^{1-\sigma} L$ *and the producers are supposed to be all myopic (i.e., they only consider their own short-term profits), they will simultaneously industrialize at the beginning but end up when their profits become negative (pattern (iv): ruinous competition). And if* $(1-\rho)(\frac{C^I}{\rho})^{1-\sigma}L < F$*, the industrialization process will not start (pattern (ii): unindustrialization).*

It is worth noting that patterns (i), (ii), and (iii) are stable equilibrium, while pattern (iv) is unstable, which could turn into pattern (i) through the consolidation and acquisition of monopoly power as described by Lamoreaux (1980) or turn into pattern (iii) with the increasing of information efficiency.

Finally, substituting $\pi_{(n)} = 0$ into Equation (2.23) yields:

$$\frac{(1-\rho)(\frac{C^I}{\rho})^{1-\sigma}L-F\{[(\frac{C^I}{\rho})^{1-\sigma}-1]n+1\}}{[\rho(\frac{C^I}{\rho})^{1-\sigma}-1]n+1} = 0 \qquad (2.25)$$

from which the fraction of industrializing sectors in partial industrialization can also be expressed as a function of the model's parameters as follows:

$$n(\pi_{(n)} = 0) = \frac{(1-\rho)(\frac{C^I}{\rho})^{1-\sigma}L-F}{F[(\frac{C^I}{\rho})^{1-\sigma}-1]} \qquad (2.26)$$

Regarding these industrialization patterns obtained, we can investigate the necessary conditions for them to appear, some of which are proven in the Appendix. Based on the investigation results, we can present these conditions in Figs. 2 and 3.

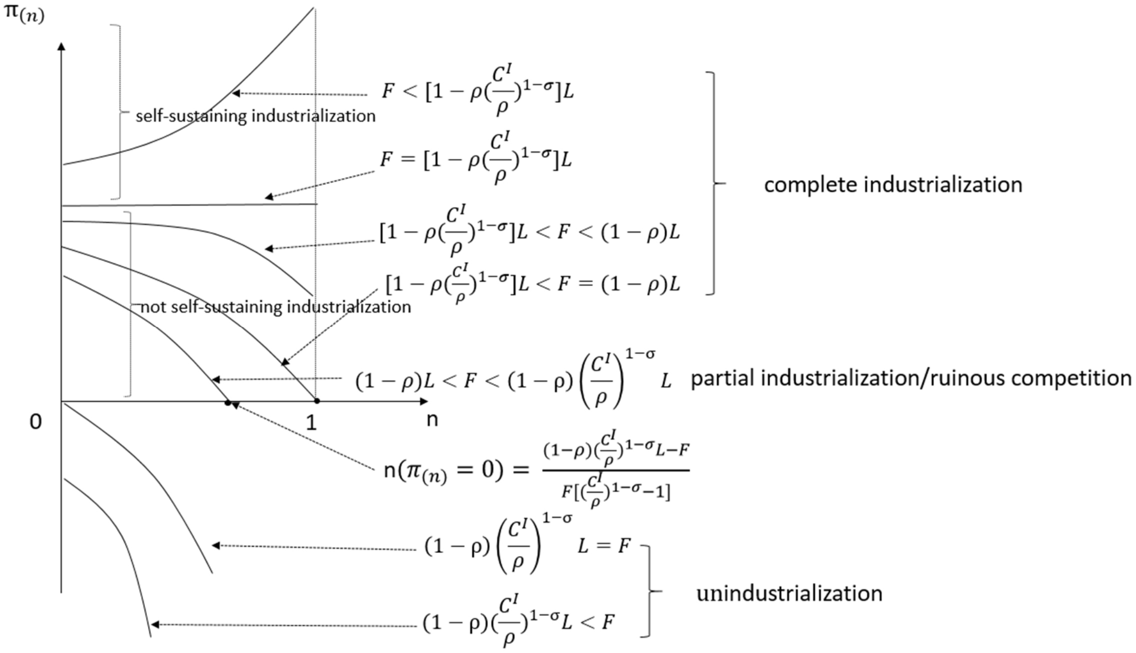

Fig. 2.2 Industrialization process for Case (II) in which $\mathbf{1-(\frac{C^I}{\rho})^{1-\sigma} \leq 0}$

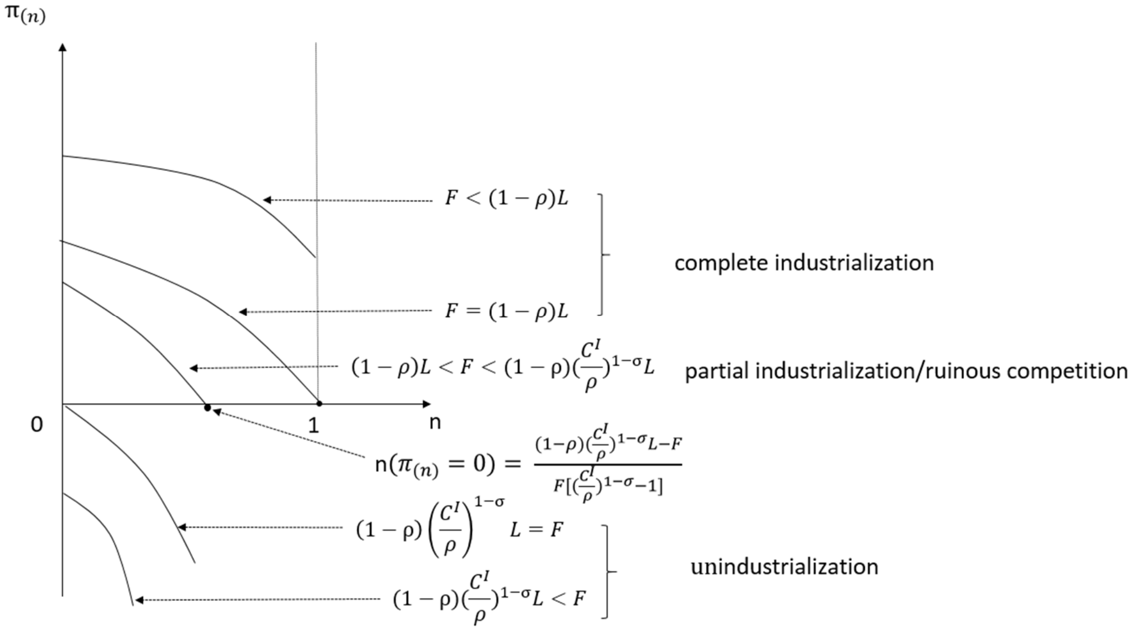

Fig. 2.3 Industrialization process for Case (II) in which $1-(\frac{C^I}{\rho})^{1-\sigma} > 0$

So far, by taking product substitutability into consideration, we uncovered the neglected industrialization patterns (iii) and (iv) and showed how high substitutability could lead to price-cutting and the business-stealing effect, which makes the industrialization process not self-sustaining even when the first industrialized sector has a positive profit. The findings of business-stealing effect and the pattern of partial industrialization and ruinous competition in the industrialization process can be considered as a contribution to the MSV model. They have an important policy implication that in addition to market size, productivity of industrialization and investment cost, product substitutability should be one more critical factor that could maintain prices and the positive profits of industrialized sectors during the industrialization process.

Similar to MSV, we also showed that large market, high productivity of industrialization production and small investment cost lead to industrialization. That is, (a) as shown in the three figures, the necessary condition for complete industrialization is $F < (1 - C^I)L$, which implies that large market, high productivity of production and small investment cost contribute to such industrialization. (b) Figs. 2 and 3 illustrated that the necessary condition for partial industrialization is $(1 - \rho)L < F < (1 - \rho)(\frac{\mathrm{C^I}}{\rho})^{1-\sigma}L$, and that for unindustrialization is $F > (1 - \rho)(\frac{\mathrm{C^I}}{\rho})^{1-\sigma}L$, which imply that industrialization is more likely to start with a larger market, higher productivity of the production and smaller investment cost. (c) Figs. 2 and 3, the industrialization level in the partial industrialization, i.e., $n(\pi_{(n)} = 0)$ increases with the market size (since $\frac{\mathrm{d}n(\pi_{(n)}=0)}{\mathrm{d}L} > 0$). (d) In Fig. 2, the necessary condition for the self-sustaining industrialization is shown to be $F < L[1 - (\frac{C^I}{\rho})^{1-\sigma}]$, which implies that large market and small investment cost contribute to the realization of self-sustaining industrialization.

2.5 Conclusion

The analysis in this paper illustrated the role of product substitutability in the industrialization process and discussed the mechanism underlying product substitutability, price-cutting strategy and industrialization patterns. The main findings are as follows. (a) When product substitutability is relatively low, the cost-reducing firms will not cut prices to steal the sales from other sectors, and the industrialization process will be self-sustaining. (b) When product substitutability is relatively high, industrializing firms will conduct the price-cutting strategy to steal business away from other sectors, and the business-stealing effect will occur. Regarding this effect, if the aggregate demand spillovers dominate it, the profits of industrialization will *rise* with the progress of industrialization, and the industrialization process will be self-sustaining. Conversely, if the business-stealing effect dominates aggregate demand spillovers, the profits of industrializing firms will *decline* with the progress of industrialization, and industrialization will no longer be a self-sustaining process.

Moreover, these two possibilities of industrialization profits suggest that there are four industrialization patterns: (i) *complete industrialization*, (ii) *unindustrialization*, (iii) *partial industrialization,* and (iv) *ruinous competition.* Patterns (iii) and (iv) were not mentioned in MSV because they neglected the role of product substitutability and the associated business-stealing effect.

The policy implication of this paper is that in addition to the important roles of market scale, the productivity of production, and investment cost as has been noted in MSV, raising product differentiation is also critical in the realization of self-sustaining industrialization.

The major conclusion of this paper is also useful for the understanding of the productivity gap across regions and/or countries. First, since the substitutability is relatively high for raw materials[20] [21], this paper sheds light on the formation of the so-called resource curse [22]. Second, since the substitutability is relatively low for high-tech goods, high-tech industries always act as the engines of economic growth (Moretti, 2013). Third, since a low level of per capita income is always associated with high substitutability[23], this model can also be useful to understand the formation of the so-called low-level equilibrium trap [24].

Although this paper unveiled the role of product substitutability in the industrialization process, the *social welfare aspect* remains unclear. Shleifer and Vishny

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[20] Rauch (1999) divided goods into three categories—commodities, reference-priced goods, and differentiated goods—based on whether they were traded on organized exchanges, were listed as having a reference price, or could not be priced by either of these means. Commodities and reference-priced goods are probably correlated with more substitutable goods. Generally, most raw materials are classified into these two categories.

[21] Broda and Weinstein (2006) estimated elasticities of substitution for a large number of internationally traded goods based on the D-S model and showed that raw materials (i.e., crude oil from petroleum or bituminous minerals, iron and steel flat-rolled products, clad, etc.) have high substitutability; meanwhile, high-tech goods (i.e., thermionic, cold cathode, photocathode valves, etc.; motor cars and other motor vehicles; telecommunications equipment, n.e.s. and pts, n.e.s.; and automatic data process machs and the units thereof) and branded goods (i.e., footwear) have low substitutability.

[22] One of the influential papers related to the resource curse is Jeffrey and Andrew (1995).

[23] For example, Gossen (1983, p.157) illustrated that for each individual, the sphere of necessities widens as income increases (in Gossen’s work, necessities mean goods with low substitutability).

[24] Nelson (1956, p. 894) defined the low-level equilibrium trap as a stable equilibrium level of per capita income at or close to subsistence requirements. Only a small percentage, if any, of the economy's income is directed toward net investment.

(1988, p. 1225) indicated that once substitutability is considered in the industrialization process, social welfare analysis would become very complex. They wrote:

> "The situation becomes more complex when *demand is elastic,* and the *cost-reducing* firm raises consumer surplus and so may raise welfare even when its investment does not break even. However, it also *steals sales and profits* from cost-reducing firms in other sectors to recoup its fixed cost and thus may reduce welfare even when its own investment is profitable. The interplay of these two opposing effects can lead to either too little or too much investment by potential cost-reducing firms."

That is, on one hand, cost-reducing firms lower market price and raise consumer surplus, and on the other hand, they also steal sales and profits from the other sectors, which can lead to too little investment. This issue is left for future work.

2. A Appendix

2.A.1 Derivation of Proposition 3 and Proposition 4

To derive Propositions 3 and 4, we need to investigate the sigh of $\frac{d\pi_{(n)}}{dn}$. For the purpose, we note that a monopolist raises the demand (profits) of other sectors *if and only if* it makes a positive profit itself. In other words, unprofitable investment reduces income and then the size of other sectors' markets. That is, (a) if $\pi_{(n)} < 0$, then $\frac{d\pi_{(n)}}{dn} < 0$. Additionally, we also know that even if the monopolist's profit is zero, it also reduces the size of other firms' markets through its price-cutting strategy, i.e., (b) if $\pi_{(n)} = 0$, then $\frac{d\pi_{(n)}}{dn} < 0$. (a) and (b)can be concluded as: if $\pi_{(n)} \leq 0$, then $\frac{d\pi_{(n)}}{dn} < 0$ for $n \in [0,1]$ which means the following Lemma:

Lemma 1 *Given that* $C^I/\rho < 1$, *if* $\pi_{(0)} \leq 0$, *then* $\frac{d\pi_{(n)}}{dn}$ *<0 for* $n \in [0,1]$, *and then,* $\pi_{(n)} \leq 0$ *for* $n \in [0,1]$,

This lemma can be proven as follows.

Step (I). Given that $n \leq 1$, $\sigma > 1, 0 < \rho < 1$ and $C^I/\rho < 1$, the subtrahend in differential equation (24) is positive, i.e., $\left(\frac{F[(\frac{C^I}{\rho})^{1-\sigma}-1]}{[\rho(\frac{C^I}{\rho})^{1-\sigma}-1]n+1}\right)>0$.

Step (II). Given that $\frac{F[(\frac{C^I}{\rho})^{1-\sigma}-1]}{[\rho(\frac{C^I}{\rho})^{1-\sigma}-1]n+1} > 0$, if $\pi_{(n)} = 0$, (24) $\frac{d\pi_{(n)}}{dn} = -\frac{F[(\frac{C^I}{\rho})^{1-\sigma}-1]}{[\rho(\frac{C^I}{\rho})^{1-\sigma}-1]n+1} <$ 0 for $n \in [0,1]$.

Step (III). Given that $\frac{F[(\frac{C^I}{\rho})^{1-\sigma}-1]}{[\rho(\frac{C^I}{\rho})^{1-\sigma}-1]n+1} > 0$, if $\pi_{(n)} < 0$, one necessary condition for $\frac{[1-\rho(\frac{C^I}{\rho})^{1-\sigma}]}{[\rho(\frac{C^I}{\rho})^{1-\sigma}-1]n+1}\pi_{(n)} - \frac{F[(\frac{C^I}{\rho})^{1-\sigma}-1]}{[\rho(\frac{C^I}{\rho})^{1-\sigma}-1]n+1}$>0 will be $[1-\rho(\frac{C^I}{\rho})^{1-\sigma}] < 0$. So, if $\pi_{(n)} < 0$, then the condition of $\frac{[1-\rho(\frac{C^I}{\rho})^{1-\sigma}]}{[\rho(\frac{C^I}{\rho})^{1-\sigma}-1]n+1}\pi_{(n)} - \frac{F[(\frac{C^I}{\rho})^{1-\sigma}-1]}{[\rho(\frac{C^I}{\rho})^{1-\sigma}-1]n+1}$ ≥0 will be $\pi_{(n)} \leq \frac{F[(\frac{C^I}{\rho})^{1-\sigma}-1]}{[1-\rho(\frac{C^I}{\rho})^{1-\sigma}]}$. However, from Equation (23), one can obtain $\pi_{(n)} > \frac{F[(\frac{C^I}{\rho})^{1-\sigma}-1]}{[1-\rho(\frac{C^I}{\rho})^{1-\sigma}]}$, which contradicts the necessary condition under $\frac{d\pi_{(n)}}{dn} \geq 0$. Therefore, if $\pi_{(n)} < 0$, then $\frac{d\pi_{(n)}}{dn} < 0$ for $n \in [0,1]$.

Finally, the results of Steps (II) and (III) can be combined to yield the following: if $\pi_{(n)} \leq 0$, then $\frac{d\pi_{(n)}}{dn} < 0$ for $n \in [0,1]$.

Using Lemma 1, differential equation (2.24) and the inequality $\frac{F[(\frac{C^I}{\rho})^{1-\sigma}-1]}{[\rho(\frac{C^I}{\rho})^{1-\sigma}-1]n+1} > 0$, we can obtain the following lemma.

Lemma 2 *Given* $C^I/\rho < 1$, *if* $1-\rho(\frac{C^I}{\rho})^{1-\sigma} \leq 0$, *then* $\frac{d\pi_{(n)}}{dn}$*<0 for* $n \in [0,1]$.

This lemma can be obtained as follows.

Step (I). Given that $1-\rho(\frac{C^I}{\rho})^{1-\sigma}<0$ and $\pi_{(n)}>0$, since $\frac{[1-\rho(\frac{C^I}{\rho})^{1-\sigma}]}{[\rho(\frac{C^I}{\rho})^{1-\sigma}-1]n+1}\pi_{(n)}<0$ and $\frac{F[(\frac{C^I}{\rho})^{1-\sigma}-1]}{[\rho(\frac{C^I}{\rho})^{1-\sigma}-1]n+1}>0$, then we have $\frac{d\pi_{(n)}}{dn}=\frac{[1-\rho(\frac{C^I}{\rho})^{1-\sigma}]}{[\rho(\frac{C^I}{\rho})^{1-\sigma}-1]n+1}\pi_{(n)}-\frac{F[(\frac{C^I}{\rho})^{1-\sigma}-1]}{[\rho(\frac{C^I}{\rho})^{1-\sigma}-1]n+1}<0$ for $n\in[0,1]$.

Step (II). Given that $1-\rho(\frac{C^I}{\rho})^{1-\sigma}<0$ and $\pi_{(n)}\leq 0$, then $\frac{d\pi_{(n)}}{dn}<0$ for $n\in[0,1]$ (due to Lemma 1).

Steps (I) and (II) means the following: if $1-\rho(\frac{C^I}{\rho})^{1-\sigma}<0$, then $\frac{\partial\pi_{(n)}}{\partial n}<0$ for $n\in[0,1]$.

Moreover, substituting $n=0$ into differential equation (2.24), we can obtain the following lemma.

Lemma 3 *Given that* $C^I/\rho<1$ *and* $1-\rho(\frac{C^I}{\rho})^{1-\sigma}>0$, *if* $\pi_{(0)}>\frac{F[(\frac{C^I}{\rho})^{1-\sigma}-1]}{1-\rho(\frac{C^I}{\rho})^{1-\sigma}}$, *we have* $\frac{d\pi_{(n)}}{dn}>0$ *for* $n\in[0,1]$. *If* $\pi_{(0)}=\frac{F[(\frac{C^I}{\rho})^{1-\sigma}-1]}{1-\rho(\frac{C^I}{\rho})^{1-\sigma}}$, *we have* $\frac{d\pi_{(n)}}{dn}=0$ *for* $n\in[0,1]$. *And if* $\pi_{(0)}<\frac{F[(\frac{C^I}{\rho})^{1-\sigma}-1]}{1-\rho(\frac{C^I}{\rho})^{1-\sigma}}$, *we have* $\frac{d\pi_{(n)}}{dn}<0$ *for* $n\in[0,1]$.

Finally, combining Lemmas 2 and 3 together, we can summarize the following lemma on how monopolistic profits change with the industrialization level.

Lemma 4 *Given that* $C^I/\rho < 1$ *and* $1-\rho(\frac{C^I}{\rho})^{1-\sigma} > 0$, *if* $\pi_{(0)} > \frac{F[(\frac{C^I}{\rho})^{1-\sigma}-1]}{1-\rho(\frac{C^I}{\rho})^{1-\sigma}}$, *then* $\frac{d\pi_{(n)}}{dn} > 0$ *for* $n \in [0,1]$*; if* $\pi_{(0)} = \frac{F[(\frac{C^I}{\rho})^{1-\sigma}-1]}{1-\rho(\frac{C^I}{\rho})^{1-\sigma}}$, *then* $\frac{d\pi_{(n)}}{dn} = 0$ *for* $n \in [0,1]$*; and if* $\pi_{(0)} < \frac{F[(\frac{C^I}{\rho})^{1-\sigma}-1]}{1-\rho(\frac{C^I}{\rho})^{1-\sigma}}$, *then* $\frac{d\pi_{(n)}}{dn} < 0$ *for* $n \in [0,1]$. *On the other, given that* $C^I/\rho < 1$, *if* $1-\rho(\frac{C^I}{\rho})^{1-\sigma} \leq 0$, *then* $\frac{d\pi_{(n)}}{dn}<0$ *for* $n \in [0,1]$.

In addition we can see that both $\pi_{(0)}$ and $\pi_{(1)}$ can be determined by parameters $\rho, F,$ C^I and L. In fact, substituting $n = 0$ and $n = 1$ into Equation (2.23) separately, we can obtain the following:

$$\pi_{(0)} = (1-\rho)(\frac{C^I}{\rho})^{1-\sigma}L - F \tag{2A.1}$$

$$\pi_{(1)} = \frac{(1-\rho)(\frac{C^I}{\rho})^{1-\sigma}L-(\frac{C^I}{\rho})^{1-\sigma}F}{\rho(\frac{C^I}{\rho})^{1-\sigma}} \tag{2A.2}$$

Using Lemmas 1, 2, 3, and 4 and Equations (2A.1) and (2A.2), we can derive Propositions 3 and 4.

Chapter 3 Fixed Capital, Comparative Advantage and Regional Manufacturing Structures

3.1 Introduction

The notable early contributions of Ricardo (1817) and Ohlin (1933) illustrated how comparative advantage and manufacturing structures[25] at the national level (or international trade patterns) are determined by the technology and natural endowment differences across countries. Krugman (1979, 1980) introduced differentiated consumer goods into this traditional trade theory, which became the foundation of the new trade theory (NTT). Noticing that "producer goods are in fact much more prominent in trade than are consumer goods", Ethier (1979, 1982) shifted the view from consumer goods to differentiated producer goods (or intermediate goods), which were assumed to have increasing returns to scale (IRS) due to the division of labor. Later, along the line of differentiated intermediate goods, Mastuyama (1996) further divided the manufacturing activities with IRS into two industries based on their input intensities: the intermediate input-intensive high-tech industry and the labor-intensive commodity industry. He showed that the production costs of the two final products decrease with the increase in the variety of intermediate inputs (due to the increasing returns). Meanwhile, as assuming the intermediate inputs more intensively, the local high-tech industry benefits

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[25] In this paper, we define the manufacturing structure as the allocation of different manufacturing activities across manufacturing industries. Notice that this is different from that in the "industrial transformation" literature, which focuses on the reallocation of economic activity across broad sectors such as agriculture, manufacturing and services (Clark, 1957; Chenery, 1960; Kuznets, 1966; See Herrendorf et al., 2014 for a review).

more from increasing returns generated by the variety of intermediate inputs. As the result, a country endowed with a wider variety of intermediate inputs acquires a comparative advantage in the high-tech industry and specializes in it. However, the above mentioned models fail to consider the movement of regional production factors, they are not able to explain the formation of comparative advantage and manufacturing structures at the subnational level, which is featured by the interregional movement of labor.

Turning to the regional economic literature, it seems that little attention has been paid to the formation of comparative advantage and regional manufacturing structure. Indeed, Krugman (1991) has built a two-region model showing that a low level of transport cost and a high level of elasticity of substitution toward variety induce the agglomeration of manufacturing activities in one region, which triggered extensive research along this line generally known as the new economic geography (NEG). However, under the *symmetric assumption* on the production of the variety goods (Dixit and Stiglitz, 1977),[26] most NEG studies fail to model the characteristics of different manufacturing activities, and only think that manufacturing activities are generally aggregated into one set of the variety goods.[27] In this sense, few NTT and NEG studies have investigated the formation of regional manufacturing structures (Tan and Zeng, 2104, pp. 230).

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[26] In Dixit and Stiglitz (1977, pp. 304-308) they considered a case in which there are two sets of variety goods with different production technologies and a constant elasticity sub-utility functions. But, within each set, firms are still symmetric and only one set of variety goods appear in equilibrium the.

[27] Specifically, most models divided economic activities into an agricultural sector with constant returns to scale agricultural sector and a manufacturing sector consisting of a set of variety goods, without distinguishing among different manufacturing activities.

In the real world, however, different manufacturing industries differ in the degree to which they rely on the local variety of intermediate goods, i.e., manufacturing activities are not symmetric. Early work by Porter highlighted the importance of clusters in a firm’s strategic location decisions (Porter, 1980, 1990). Porter (1998) argued that sharing the variety goods is especially important for “advanced and specialized industries involving embedded technology, information, and service content.” In the footloose capital (FC) model (Martin and Rogers, 1995), the local capital amount was used to represent the local variety of manufacturing activities. Generally, if high-tech industries can benefit more from the local variety, they will tend to locate in the capital-abundant regions, which supply a larger variety of intermediate inputs. In contrast, regions with less fixed capital tend to have a larger share of commodity or low-tech industries, such as the textile industry, which is labor-intensive.

Fujita and Hu (2001) investigated the regional manufacturing structure transition in China from 1980 to 1994. They and others showed that in the 1980s and 1990s, several plants were built using foreign direct investment (FDI) on the east coast of China (see Tables 1 and 2). In that region, the manufacturing structure became characterized by the agglomeration of high-tech industries, which were heavily based on the inputs of intermediate goods. For example, in 1980, only 10% of washing machines and 19% of electric fans were produced in Guangdong, a coastal province near Hong Kong. And, no recorders, color TVs, or cameras were produced at that time. However, since 1980 when FDI began to increase in Guangdong, an agglomeration of electronics industries appeared. As a result, in 1994, the shares of digital wristwatches, recorders, color TVs, and cameras produced in Guangdong increased to 90%, 86%, 27%, and 84%, respectively (see Table 3).

Table 3.1 Regional distribution of investment in fixed assets in China

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
East/West	1.12	1.12	1.23	1.38	1.48	1.49	1.44	1.47	1.63	1.79	1.93
Provincial CV	0.60	0.60	0.65	0.71	0.74	0.61	0.71	0.73	0.82	0.84	0.85

CV: coefficient of variation

East: the amount of investment in the coastal provinces (Liaoning, Hebei, Beijing, Tianjin, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangxi, Guangdong, Hainan)

West: the amount of investment in the other provinces

Data Source: Fujita and Hu (2001)

Table 3.2 Regional distribution of fixed capital stock in China

	1978	1985	1990	1995	2000	2004
East/West	0.80	1.01	1.27	1.67	1.82	1.88

East: the amount of fixed capital stock in the coastal provinces

West: the amount of fixed capital in the other provinces

Data Source: Zhang, Wu and Zhang (2007)

Table 3.3 Electronics production in Guangdong as a percentage of national total production

	1980	1985	1990	1993	1994
Washing machines	9.88	8.78	21.58	27.15	22.59
Electric fans	19.05	41.27	56.27	56.68	65.18
Recorders	0.00	35.87	53.81	76.93	86.25
Color TVs	0.00	18.15	25.40	29.38	26.76
Cameras	0.00	10.44	46.57	89.63	83.65

Data Source: Fujita and Hu (2001)

Similar, in Japan, the variety of the supply of local intermediate inputs is also very attractive to high-tech manufacturing industries. Fujita et al. (2004) examined the regional structures of manufacturing industries in East Asia and Japan and found that the spatial concentration of the machinery-metal industries presents a strong evidence of "*linkage-based agglomeration economies*". That is, such industries tend to locate together and concentrate in Japanese Core prefectures (J-Core) (The prefectures of Tokyo, Kanagawa, Aichi, Osaka and Hyogo).[28]In contrast, however, the textile-apparel industries show weak linkage-based agglomeration economies. In 1955, they accounted for 15% of the total manufacturing GDP of Japan, of which 45% was concentrated in the J-Core. However, in 1985, Japan was among the weakest of these industries (within East Asia), and they were among the least agglomerated in the J-Core. Such an industrial structure change in Japan is illustrated in Fig. 3.1.

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[28] Porter (1990) extensively discussed such linkage-based agglomeration economies in Japan.

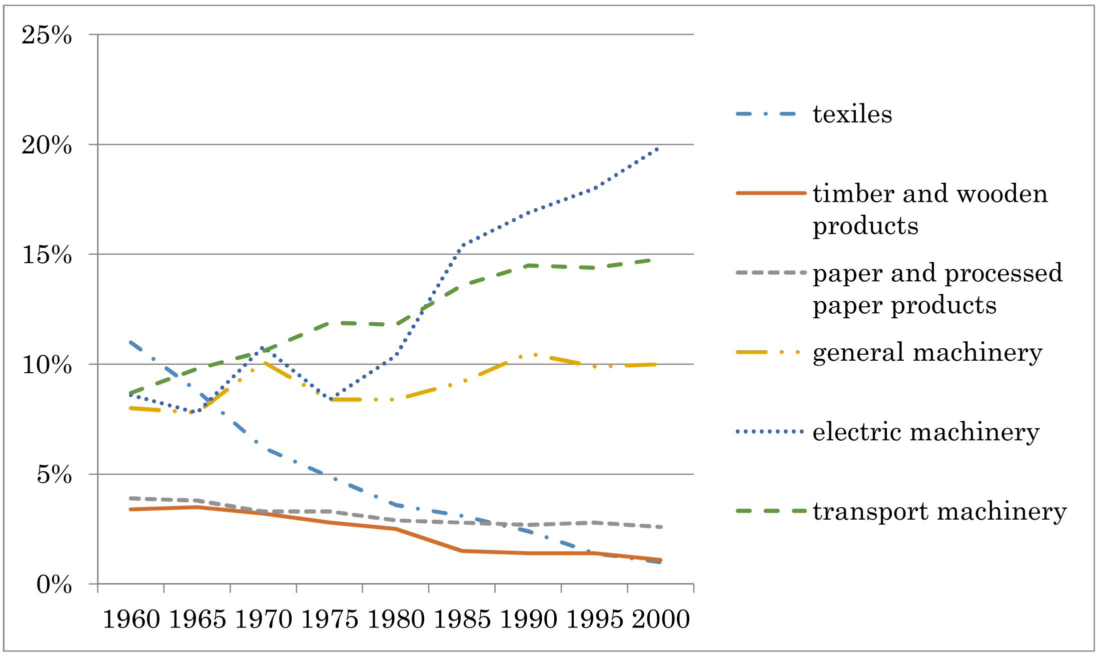

Fig. 3.1 Nominal revenue shares of selected two-digit industries in Japan's total manufacturing production[29]

As has been seen, the relations between regional fixed capital stocks and manufacturing structures are widely observed, but, to our knowledge, their microeconomic foundation has not been found. Recently, there appeared several following attempts at incorporating the classical comparative advantage theory into the NTT and NEG frameworks. Venables (1999) examined the role of *Ricardian differences* in the spatial distribution of different industries. In his model, labor was the only production factor and a comparative advantage arose from the exogenous technological difference among countries, as in Ricardo (1817). Adding capital as another production factor, Amiti (2005) extended the NEG model by embedding a vertical industrial linkage (Venables, 1996) into a *Hechscher-Ohlin framework* to

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[29] Data Source: Census of Manufacturers (http://www.meti.go.jp/statistics/tyo/kougyo/library/library_1.html#menu1, checked on 2018.09.27)

examine the location of vertically linked manufacturing firms. Recently, Tan and Zeng (2013) incorporated both Ricardian and Hechscher-Ohlin advantages into a FC model. Unfortunately, all of these studies were based on the assumed *exogenous interregional productivity gap,* which determined local comparative advantage and industrial structures, without explaining how the productivity gap was formed. As far as we know, this paper is the first attempt to endogenize both of regional productivities and comparative advantages. It can be considered a contribution to the literature of comparative advantage.

In addition, there have been several empirical studies attempting to deconstruct the sources of competitive advantage based on local embeddedness (Martin and Sunley 2003, Schotter et al., 2017; Wójcik et al., 2018; Goerzen, 2013). But they have not taken local fixed capital stock into consideration.

Based on the above literature review, this paper aims to answer the following questions. How does the local variety of intermediate inputs (as reflected by the local fixed capital stock) of a region relate to the local manufacturing productivity and the corresponding local comparative advantage? With this local comparative advantage, how are regional manufacturing structures formed, and how is the population distributed across regions?

Specifically, as done in the Matsuyama (1996) model, we distinguish manufacturing activities into intermediate input-intensive (high-tech industries) and labor-intensive (low-tech) industries. And, similar to the FC model, we use the local fixed capital stocks to represent the local variety of intermediate inputs. We connect the local variety of intermediate input with the local productivity, which enables our endogenous analysis of the local productivity. Then, we show that the region enjoying more fixed capital has an absolute advantage in the two manufacturing industries and a comparative advantage in the capital-intensified high-tech industry. This leads to such regional manufacturing structures, that, the capital-abundant region has larger revenues of the two manufacturing industries (reflecting the absolute advantage) with a larger revenue ratio of the high-tech to low-tech industries (reflecting the comparative advantage).

In the next section, we describe the basic structure of the economy. In Section 3.3, we first discuss the role of the spatial distribution of fixed capital stock in the formation of regional absolute and comparative advantages and then show how such distribution determines the regional manufacturing structure. We also provide some empirical evidence from China. In Section 3.4, we examined the spatial distribution of population. Section 3.5 concludes the paper.

3.2 The Autarky Economy

In this section, we extend the Matsuyama (1996) model to an autarky economy with two industries and two production factors by introducing the fixed capital as an additional production factor as in the FC model. In particular, we assume that one unit of fixed capital associated with labor are inputted into the production of one variety of intermediates, so the amount of fixed capital stock is equal to that of the variety of intermediates. Such fixed capital stock can be considered as accumulated through all kinds of local fixed capital investments, such as investments in infrastructures, industrial plants and production equipment.

The endowment of the autarky economy is L units of labor and K units of fixed capital. Laborers are supplied to the high-tech industry, low-tech industry and intermediate goods sector. Due to the free movement of labor, wages are equal cross the three sectors, denoted by ω.

The fixed capital is owned in common by laborers, and the capital revenue is equally divided among the laborers. If one unit of fixed capital generates capital rental (*r*), then the total capital revenue becomes $K\ r$. Laborers' (Consumers') total income $L\omega + K\ r$ is used to consume *T* units of high-tech goods *C* units of the low-tech goods. Given that the amount of numeraire in the economy is denoted by *Y*, total revenue can be expressed as $Y = P^C C + P^T T$ (P^C and P^T are the prices of high-tech and low-tech goods, respectively), and total income can also be written as $Y = L\omega + K\ \mathrm{r}$.

3.2.1 Consumption of Goods

Suppose that the representative consumer has a Cobb-Douglas preference over the two consumption goods, which can be represented by the following utility function:

$$U = R_u C^{1-\gamma} T^{\gamma}\ ,\ 0 < \gamma < 1 \qquad (3.1)$$

where R_u is a constant parameter given as $R_u = (1-\gamma)^{\gamma-1}\gamma^{-\gamma}$, γ is the share of the high-tech goods in the consumer's expenditure, and $1-\gamma$ is that of the low-tech goods.

Denote P^C and P^T as the prices of the low-tech and high-tech goods, respectively. The consumer's problem is to maximize his or her utility function subject to the income budget constraint by choosing adequate amounts of consumption goods, which is expressed as follows:

max $U = R_u C^{1-\gamma} T^{\gamma}$;

(C, T) (3.2)

s.t. $Y = P^C C + P^T T$

The results of (3.2) yield:

$$Y^C = C^D P^C = (1-\gamma)Y \tag{3.3}$$

$$Y^T = T^D P^T = \gamma Y \tag{3.4}$$

where C^D and T^D denote the consumer's demand for the low-tech and high-tech goods, respectively, and Y^C and Y^T express the revenue of the low-tech and high-tech industries, respectively.

3.2.2 Production of Consumption Goods

Suppose that the two consumption goods are produced competitively with constant-returns-to-scale technologies. The inputs are labor and the differentiated intermediate goods, which are combined with Cobb-Douglas technologies, with α_C and α_T being the input shares of intermediates in the low-tech and high-tech industries, respectively. So, the amount of the low-tech goods supplied, denoted as C^S, and that of the high-tech goods, denoted as T^S, can be given as follows:

$$C^S = R_C {L^C}^{1-\alpha_C} {X^C}^{\alpha_C}, \ 0 < \alpha_C < 1 \tag{3.5}$$

$$T^S = R_T {L^T}^{1-\alpha_T} {X^T}^{\alpha_T}, \ 0 < \alpha_T < 1 \tag{3.6}$$

where $R_C[\equiv (1-\alpha_C)^{\alpha_C-1})\alpha_C{}^{-\alpha_C}]$ and $R_T[\equiv (1-\alpha_T{}^{\alpha_T-1})\alpha_T{}^{-\alpha_T}]$ are two constants. X^C and X^T denote the amounts of intermediates inputted into the production of the low-tech and high-tech goods, respectively. L^C and L^T are the amounts of labor used in the low-tech and high-tech industries, respectively. α_C and α_T denote the shares of intermediates used in the production of low-tech and high-tech goods, respectively. Here, we impose an important assumption that $\alpha_C < \alpha_T$. That is, the high-tech industry uses the intermediate goods *more intensively* than does the low-tech industry.

The above Cobb-Douglas production functions imply that the rewards of intermediate goods and labor in the revenue of each industry can be expressed as follows:

$$X^C P^X = \alpha_C Y^C \tag{3.7a}$$

$$X^T P^X = \alpha_T Y^T \tag{3.7b}$$

$$L^C \omega = (1-\alpha_C)\, Y^C \tag{3.8a}$$

$$L^T \omega = (1-\alpha_T) Y^T \tag{3.8b}$$

where P^X denotes the price index of intermediate goods. That is, in the low-tech industry, proportion α_C of cost and hence of revenue goes to the intermediate goods sector, and $1-\alpha_C$ of that goes to laborers. In the high-tech industry, such proportions for labor and intermediate goods are α_T and $1-\alpha_T$, respectively.

3.2.3 Production of Intermediate Goods

The differentiated intermediate goods are assumed to be supplied by local monopolistically competitive firms. Each of them is supplied by a monopolistic firm, which uses a marginal input of labor and a fixed input of fixed capital. Like many NEG works, we can choose the units of fixed capital and intermediate goods so that a fixed input of one unit of capital and a marginal input of $(\sigma - 1)/\sigma$ units of labor are required to produce one unit of a variety. Thus, the variety of intermediate goods is equal to the fixed capital stock *K*. As done in Dixit-Stiglitz (1977), the local intermediate goods are aggregated as follows:

$$X = [\int_0^K x(z)^{\frac{\sigma-1}{\sigma}} dz]^{\frac{\sigma}{\sigma-1}},\ \sigma > 1 \tag{3.9}$$

where *K* is the range of differentiated intermediate goods (or the amount of fixed capital), $x(z)$ is the amount of the *z*th variety of intermediate goods, and σ (> 1) represents the elasticity of substitution between any two intermediate varieties. The cost minimization in using the intermediates yields the price index of intermediates as follows:

$$P^X = (\int_0^K p(\mathrm{z})^{\frac{\sigma}{\sigma-1}}\, dz)^{\frac{\sigma-1}{\sigma}} \tag{3.10}$$

where $p(\mathrm{z})$ is the price of intermediate goods of the *z*th variety.

Given that a fixed input of one unit of capital and a marginal input of $(\sigma - 1)/\sigma$ units of labor are inputted in the production of each variety, the profit for a plant to produce $x(\mathrm{z})$ units of the *z*th intermediate good can be written as:

$$\pi(z) = p(z)x(z) - \omega\frac{\sigma-1}{\sigma}x(z) - r \tag{3.11}$$

where r is the capital rental of using one unit of fixed capital. Since the supply of intermediate goods is monopolistically competitive, that is, each plant determines its price of intermediate goods monopolistically, its profit-maximizing solution yields:

$$p(\mathrm{z})\left(1-\frac{1}{\sigma}\right) = \frac{\sigma-1}{\sigma}\,\omega$$

which can be simplified to:

$$p(\mathrm{z}) = p = \omega \tag{3.12}$$

Because the production technology is the same for all varieties, we can drop the subscript *z* in the relevant variables.

Furthermore, the zero-profit condition yields the rental of using one unit of fixed capital as follows:

$$\mathrm{r} = px - \omega\frac{\sigma-1}{\sigma}x = \frac{1}{\sigma}px \tag{3.13}$$

which means that the share of capital payment in the revenue for each intermediate goods plant is $\frac{1}{\sigma}$, and the share of labor payment becomes $1-\frac{1}{\sigma} = \frac{(\sigma-1)}{\sigma}$.

As the production technology is the same for all varieties, the share of labor payment and the share of capital payment are also the same across all intermediate goods plants, which are then equal to the shares in the revenue of the whole intermediate sector. Thus, the total labor payment in the revenue of the intermediate sector can be expressed as:

$$L^X \omega = \frac{(\sigma-1)}{\sigma} X P^X \tag{3.14}$$

where L^X denotes the amount of labor inputted in the intermediate goods sector. Similarly, the total capital payment in the revenue of the intermediate sector becomes

$$Kr = \frac{1}{\sigma} X P^X \tag{3.15}$$

Recall that in the low-tech industry, proportion α_C of production cost and hence of revenue goes into the intermediate goods sector, and $1-\alpha_C$ of that goes to laborers. And, in the high-tech industry, the shares of labor and intermediate goods payments are α_T and $1-\alpha_T$, respectively.

We can express the payment for the total capital in the autarky economy as follows:

$$Kr = \frac{1}{\sigma}(\alpha_C Y^C + \alpha_T Y^T) \tag{3.16}$$

And, the total labor payment in the autarky economy is equal to the total revenue minus the total capital payment, that is:

$$L\omega = (Y^C + Y^T) - \frac{1}{\sigma}(\alpha_C Y^C + \alpha_T Y^T) = \frac{(\sigma-\alpha_C)}{\sigma} Y^C + \frac{(\sigma-\alpha_T)}{\sigma} Y^T \qquad (3.17)$$

where $Y^C = P^C C$ and $Y^T = P^T T$ are the revenues of the low-tech and high-tech industries, respectively. It should be noted that (a) total labor payment here consists of not only the labor payments in the two final goods sectors but also the labor payment in the intermediate goods sector[30]. (b) Although neither industry uses fixed capital directly, their revenues flow indirectly to the fixed capital payment through the use of intermediate goods. This can be confirmed by Equation (3.16), which implies that the payment shares of fixed capital in the high-tech and low-tech industries are $\frac{1}{\sigma}\alpha_T$ and $\frac{1}{\sigma}\alpha_C$, respectively. Under the perfect competition in the final goods markets, the shares of labor payment in each industry are equal to one minus the payment shares of fixed capital, i.e., $1 - \frac{1}{\sigma}\alpha_T = \frac{(\sigma-\alpha_T)}{\sigma}$ and $1 - \frac{1}{\sigma}\alpha_C = \frac{(\sigma-\alpha_C)}{\sigma}$ in the high-tech and low-tech industries, respectively. Because the input intensities of fixed capital in the two industries have such a relation as $\frac{1}{\sigma}\alpha_T > \frac{1}{\sigma}\alpha_C$, or the input intensities of labor have such one as $\frac{(\sigma-\alpha_T)}{\sigma} < \frac{(\sigma-\alpha_C)}{\sigma}$, we can say that the high-tech industry is fixed-capital intensified while the low-tech industry is labor-intensified.

3.2.4 Unit Production Costs and Local Increasing Returns

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[30] Another way to calculate the total labor payment is to add the labor payments in two final goods sectors $(1-\alpha_C)Y^C + (1-\alpha_T)Y^T$ to the labor payment in the intermediate sector $\frac{\sigma-1}{\sigma}(\alpha_C Y^C + \alpha_T Y^T)$, which yields the same result as in Equation (3.17).

To see how increasing returns (the productivity of each industry) are associated with the local fixed capitals stock, we need to calculate the unit production costs of the two final goods industries.

Substituting Equation (3.12) into Equation (3.10), the price index of the intermediate goods can be simplified to:

$$P^X = K^{\frac{\sigma-1}{\sigma}}\omega \tag{3.18}$$

The Cobb-Douglas production functions, Equations (3.5) and (3.6), imply that the unit production costs in the two industries can be written as follows:

$$C^C = {P^X}^{\alpha_C}\omega^{1-\alpha_C} \tag{3.19}$$

$$C^T = {P^X}^{\alpha_T}\omega^{1-\alpha_T} \tag{3.20}$$

where C^C and C^T denote the unit production costs of low-tech and high-tech goods, respectively. Under the perfect competition in the final goods markets, they are equal to the corresponding market prices, that is, $C^C = P^C$and $C^T = P^T$. Furthermore, using Equation (3.18) to replace P^X in (3.19) and (3.20) yields:

$$P^C = K^{\frac{\alpha_C}{1-\sigma}}\omega \tag{3.21}$$

$$P^T = K^{\frac{\alpha_T}{1-\sigma}}\omega \tag{3.22}$$

Since $\sigma > 1$, Equations (3.21) and (3.22) imply that the unit production costs of low-tech and high-tech goods decline with the variety of intermediate goods *K*. The increasing of local productivity cause by the variety of intermediate inputs was originally modeled by Ethier (1977, 1982), who attributed them to the division of labor suggested by by Adam Smith using the examples of pin factory and Swiss watch industry. In the traditional NEG model, it is assumed that consumers benefit from the variety of final goods, i.e., the increasing returns to the utility. In this paper, we assume that the final goods industries benefit from the variety of intermediate inputs because the unit production costs of low-tech and high-tech goods decline with the variety of intermediate goods. Furthermore, we also assume that $\alpha_C < \alpha_T$, which implies that the unit production cost declines faster in the high-tech industry than in the low-tech industry.

3.3 A Two-region Economy

In this section, we extend the above autarky economy to a two-region economy comprising the eastern region (Region *E*) and western region (Region *W*), while the numeraire endowment of the two-region economy is retained to be *Y*. Suppose that Region *E* is endowed with more fixed capital stock than Region *W* (like the case of China), and the ratio of the local fixed capital stock in Region *E* to that in Region *W* is denoted as φ, that is, $\varphi \equiv \frac{\mathrm{K}_E}{\mathrm{K}_W}(> 1)$, where K_E and K_W are the amount of fixed capital stock in Region *E* and *W*, respectively. Such a spatial distribution of fixed capital stock, or, K_E, K_W and φ, are exogenously given by historical, geographical or political factors that are not studied here.

Denote the capital rentals in the two regions as r_E and r_W, respectively, the total capital revenue can be written as $K_E r_E + K_W r_W$, which is equally allocated to each laborer, no matter what his location.

In addition, we assume that the intermediate goods are not tradable, while the interregional trade of final goods incurs no transportation costs, as in Fujita (1988) and Rivera-Batiz (1988). Considering the shared fixed capital stock and the relatively high transportation costs of intermediate goods compared to the transportation costs of final goods, this assumption is not far from reality.[31]

3.3.1 Regional Absolute and Comparative Advantages

Here, we investigate what determines regional absolute and comparative advantages, which are associated with the formation of regional manufacturing structures to be discussed later.

Using K_E to replace *K* in Equations (3.21) and (3.22), the unit production costs of low-tech and high-tech goods (or their market prices denoted as P_E^C and P_E^T, respectively) in Region *E* can be expressed as follows:

$$P_E^C = \mathrm{K}_E^{\frac{\alpha_C}{1-\sigma}}\omega \qquad (3.23a)$$

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[31] We can consider three factors to justify this assumption: (1) intermediate goods (or local services) supplied by local infrastructure are non-tradable because of their nature; (2) the existence of economies of scale in manufacturing production (Henderson, 2003) will make production-related firms agglomerate together, hence weakening the need for cross-regional trading of parts and components; (3) these components, generally, have a larger weight per unit of value than final goods.

$$P_E^T = \mathrm{K}_E{}^{\frac{\alpha_T}{1-\sigma}}\omega \tag{3.23b}$$

Similarly, the corresponding unit production costs or market prices denoted as P_W^C and P_W^T, respectively, in Region *W* can be given as:

$$P_W^C = \mathrm{K}_W{}^{\frac{\alpha_C}{1-\sigma}}\omega \tag{3.24a}$$

$$P_W^T = \mathrm{K}_W{}^{\frac{\alpha_T}{1-\sigma}}\omega \tag{3.24b}$$

Since $K_E > K_W$ and $\sigma > 1$, it is easy to see that the unit production costs of low-tech and high-tech goods are lower in Region *E*, that is, $P_E^C < P_W^C$ and $P_E^T < P_W^T$, which implies that Region *E* has an absolute advantage in both the high-tech and low-tech industries.

Furthermore, using Equations (3.23a) and (3.23b), the relative unit production cost of low-tech goods in terms of that of high-tech goods in Region *E*, denoted by Q_E, can be written as:

$$Q_E = \frac{P_E^C}{P_E^T} = K_E{}^{\frac{\alpha_C-\alpha_T}{1-\sigma}} \tag{3.25}$$

Similarly, the relative unit production cost of low-tech goods in terms of that of high-tech goods in Region *W*, denoted by $\mathrm{Q_W}$, can be written as:

$$Q_W = \frac{P_W^C}{P_W^T} = K_W{}^{\frac{\alpha_C-\alpha_T}{1-\sigma}} \tag{3.26}$$

So, to see the comparative advantage of each region, we compare the relative unit costs between the two regions, obtaining:

$$\frac{\mathrm{Q}_E}{\mathrm{Q}_W} = (\frac{\mathrm{K}_E}{\mathrm{K}_W})^{\frac{\alpha_C - \alpha_T}{1-\sigma}} = (\varphi)^{\frac{\alpha_C - \alpha_T}{1-\sigma}} \tag{3.27}$$

This means that the comparative advantage is determined by the distribution of fixed capital or φ. Given that $\alpha_C < \alpha_T$ and $\varphi > 1$, it is easy to gain $\frac{\mathrm{Q}_E}{\mathrm{Q}_W} > 1$. So, we obtain the following Proposition.

Proposition 1 *The capital-abundant region has an absolute advantage in both high-tech and low-tech industries and has a comparative advantage in the high-tech industry, which uses fixed capital more intensively. In contrast, the region with less fixed capital has no absolute advantage but has a comparative advantage in the labor-intensive low-tech industry.*

Although some studies (e.g. Amiti, 2005; Tan and Zeng, 2013) also considered both Ricardian advantages (the productivity gap) and Hechscher-Ohlin comparative advantages (the factor endowment gap), they were based on the assumed exogenous interregional productivity gap. The endogenous explanation of both the productivity gap (absolute advantage) and the comparative advantage is a major difference between this paper and the usual comparative advantage theory.

Differentiating Equation (3.27) with respect to φ yields $\frac{d\frac{\mathrm{Q}_E}{\mathrm{Q}_W}}{d\varphi} > 0$, which means that an increase in φ will enhance the capital-abundant region's comparative advantage in the high-tech industry and the capital-poor region's comparative advantage in the low-tech industry. Moreover, $\frac{Q_E}{Q_W}$ increases with the gap of the intensities using the intermediates between the high-tech and low-tech industries, that is, $\alpha_C - \alpha_T$. In other word, larger intensity gap implies larger absolute and comparative advantages.

3.3.2 Regional Manufacturing Structures

To investigate regional manufacturing structures, we define the two following indexes, $\mu_E \equiv Y_E^T / Y_E^C$ and $\mu_W \equiv Y_W^T / Y_W^C$, to represent the manufacturing structures in Region *E* and Region *W*, respectively, where Y_E^T and Y_E^C are the revenues of the high-tech and low-tech industries in Region *E*, respectively, and Y_W^T and Y_W^C are the corresponding revenues in Region *W*.

Matsuyama (1996) showed that one country specializes in one manufacturing industry in which it has a comparative advantage. A slight change in the variety of intermediate inputs brings about a catastrophic change in the manufacturing industry in which the country specializes. To avoid catastrophic changes, using the Armington (1969) assumption,[32] we treat the final goods of the same industry but produced in different regions as differentiated goods. Specifically, we maintain the assumption that the representative consumer has a Cobb-Douglas preference for high-tech and low-tech goods with the consumption shares being γ and $1 - \gamma$, respectively, which ensures the perfect competition in the final goods markets. Furthermore, we assume that the representative consumer has an Armington (1969) type of constant elasticity of

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[32] The Armington (1969) assumption is widely used in the NTT and NEG literature. See Overman et al. (2003) for a review.

substitution (CES) subutility function about the two final goods produced in each region. That is, each region produces a kind of differentiated high-tech good and a kind of differentiated low-tech good.

Specifically, regarding the low-tech goods, we define the following subutility function:

$$C = (\mathrm{C}_E^{\frac{\eta-1}{\eta}} + \mathrm{C}_W^{\frac{\eta-1}{\eta}})^{\frac{\eta}{\eta-1}},\ \eta > 1 \tag{3.28}$$

Regarding the high-tech goods, the following subutility function is defined:

$$T = (\mathrm{T}_E^{\frac{\eta-1}{\eta}} + \mathrm{T}_W^{\frac{\eta-1}{\eta}})^{\frac{\eta}{\eta-1}},\ \eta > 1 \tag{3.29}$$

In (3.28) and (3.29), C_E and C_W are the consumption amounts of the low-tech goods produced in Region *E* and Region *W*, respectively. T_E and T_W are the consumption amounts of the high-tech goods produced in Region *E* and Region *W*, respectively. η denotes the elasticity of substitution between the similar final goods produced in different regions. The price elasticity of demand for each final goods is also η.

The representative consumer's problem is solved in two steps. First, the consumer chooses the consumption proportions of high-tech and low-tech goods under the Cobb-Douglas preference (Equation (3.1)), which yields:

$$Y^C = Y_E^C + Y_W^C = (1-\gamma)Y \tag{3.30a}$$

$$Y^T = Y_E^T + Y_W^T = \gamma Y \tag{3.30b}$$

Second, regarding the consumption amounts of low-tech goods (C_E and C_W), given their prices in each region as P_E^C and P_W^C[33], the representative consumer maximizes the total consumption subject to the expenditure on the low-tech goods (Y_C), which implies the following maximization problems:

$$\max_{(\mathrm{C}_E, \mathrm{C}_W)} C = (\mathrm{C}_E^{\frac{\eta-1}{\eta}} + \mathrm{C}_W^{\frac{\eta-1}{\eta}})^{\frac{\eta}{\eta-1}} \qquad (3.31)$$
$$\text{s.t. } P_E^C \mathrm{C}_E + P_W^C \mathrm{C}_W = Y^C = (1-\gamma)Y$$

Similarly, regarding the high-tech goods produced in the two regions, the consumer maximizes the total consumption subject to the expenditure on these goods (Y^T) by choosing the consumption amounts (T_E and T_W), which can be described as follows:

$$\max_{(\mathrm{T}_E, \mathrm{T}_W)} T = \left(\mathrm{T}_E^{\frac{\eta-1}{\eta}} + \mathrm{T}_W^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}} \qquad (3.32)$$
$$\text{s.t. } P_E^T \mathrm{T}_E + P_W^T \mathrm{T}_W = Y^T = \gamma Y$$

It can be obtained that the first-order condition of the maximization problem (3.31) yields the following revenues of low-tech industries in Regions *E* and *W*:

$$Y_E^C = Y^C \frac{1}{1+(\frac{P_W^C}{P_E^C})^{1-\eta}} = \frac{(1-\gamma)Y}{1+(\frac{P_W^C}{P_E^C})^{1-\eta}} \qquad (3.33)$$

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[33] Consider that each final goods industry in each region comprises many individual small production plants with Cobb-Douglas production technology defined in Equations (3.5) and (3.6). Then the plant will view itself as having a constant returns to scale production function, which ensures the perfect competition in the interregional final goods markets, as explained in Chipman (1970) and Henderson (1974).

$$Y_W^C = Y^C \frac{1}{1+(\frac{P_E^C}{P_W^C})^{1-\eta}} = \frac{(1-\gamma)Y}{1+(\frac{P_E^C}{P_W^C})^{1-\eta}} \tag{3.34}$$

Under the assumptions of zero transportation costs and perfect competition in the interregional final goods market, each region's unit production costs of the low-tech and high-tech goods are equal to their corresponding local market prices. Thus, using Equations (3.23a) and (3.24a) to replace P_E^C and P_W^C in (3.33) and (3.34) yields:

$$Y_E^C = \frac{(1-\gamma)Y}{1+(\varphi^{\frac{\alpha_C}{\sigma-1}})^{1-\eta}} \tag{3.35}$$

$$Y_W^C = \frac{(1-\gamma)Y}{1+(\varphi^{\frac{\alpha_C}{1-\sigma}})^{1-\eta}} \tag{3.36}$$

For simplicity, we assume $\sigma = \eta$, that is, the elasticity of substitution among varieties is equal to that among final goods[34]. So, (3.35) and (3.36) become:

$$Y_E^C = \frac{(1-\gamma)Y}{1+\varphi^{-\alpha_C}} \tag{3.37}$$

$$Y_W^C = \frac{(1-\gamma)Y}{1+\varphi^{\alpha_C}} \tag{3.38}$$

Regarding the high-tech goods, through a similar calculation process, we can obtain:

$$Y_E^T = \frac{\gamma Y}{1+\varphi^{-\alpha_T}} \tag{3.39}$$

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[34] It is harmless to assumption $\sigma = \eta$ since σ and η are both exogenous parameters which are larger than one. Removing this assumption will not change the major conclusions of this paper.

$$Y_W^T = \frac{\gamma Y}{1+\varphi^{\alpha_T}} \quad (3.40)$$

Equations (3.37), (3.38), (3.39), and (3.40) give the revenues of the two final goods industries in the two regions. Differentiating them with respect to φ yields: $\frac{dY_E^C}{d\varphi} > 0, \frac{dY_E^T}{d\varphi} > 0; \frac{dY_W^C}{d\varphi} < 0, \frac{dY_W^T}{d\varphi} < 0$, which imply that the local revenues of both the high-tech and low-tech industries in Region *E* increases with the ratio of the local fixed capital stock in region *E* to that in region *W*, while the local revenues in region *W* decreases with the ratio.

Using Equations (3.39) and (3.37), the manufacturing structure of Region *E* can be expressed as:

$$\mu_E \equiv Y_E^T / Y_E^C = \frac{\gamma}{1-\gamma} \frac{1+\varphi^{-\alpha_C}}{1+\varphi^{-\alpha_T}} \quad (3.41)$$

Similarly, using equations (3.38) and (3.39), we can express the manufacturing structure of Region *W* as follows:

$$\mu_W \equiv Y_W^T / Y_W^C = \frac{\gamma}{1-\gamma} \frac{1+\varphi^{\alpha_C}}{1+\varphi^{\alpha_T}} \quad (3.42)$$

Equations (3.41) and (3.42) yield the following Lemma.

Lemma

(i) For all $\varphi \in$ *(1,∞), we have* $\mu_E > \mu_W$. *That is, the capital-abundant region will relatively specialize in the high-tech industry, while the region with less capital will relatively specialize in the low-tech industries.*

(ii) The solution of $\frac{d\mu_E}{d\varphi} = 0$ *(denoted as "*$\bar{\varphi}$*") within (1,∞) is unique. For any* $\varphi > \bar{\varphi}$, *we have* $\frac{d\mu_E}{d\varphi} > 0$. *For any* $\varphi < \bar{\varphi}$ *(*$\varphi > 1$*), we have* $\frac{d\mu_E}{d\varphi} < 0$. *When* $\varphi \to \infty$, $\mu_E \to \frac{\gamma}{1-\gamma}$. *That is, as long as* $\varphi < \bar{\varphi}$, *the revenue share of the high-tech industry in Region E increases with* φ. *When* $\varphi \to \infty$, *the manufacturing structure in Region E (denoted by* μ_E*) approaches to the consumer's expenditure share* $\frac{\gamma}{1-\gamma}$.

(iii) For all $\varphi \in$ *(1,∞), we have* $\frac{d\mu_W}{d\varphi} < 0$. *When* $\varphi \to \infty$, $\mu_W \to 0$. *That is, the revenue share of the high-tech industry in Region W deceases with* φ. *When* $\varphi \to \infty$, *the manufacturing structure in Region W (denoted by* μ_W*) approaches to zero.*

Lemma (i) is based on $\mu_E > \frac{\gamma}{1-\gamma}$ and $\mu_W < \frac{\gamma}{1-\gamma}$. And the proofs of Lemma (ii) and (iii) are given in 3A.1 and 3A.2.

Lemma (i) corresponds to Proposition 1, suggesting that the capital-abundant and capital-poor regions have comparative advantage in the high-tech and low-tech industries, respectively.

Furthermore, as long as $\varphi < \bar{\varphi}$, the revenue share of the high-tech industry in Region *E* increases with φ, while that in Region *W* decreases with φ. That is, the larger the fixed capital gap between Region *E* and *W*, the larger the manufacturing structure gap between them.

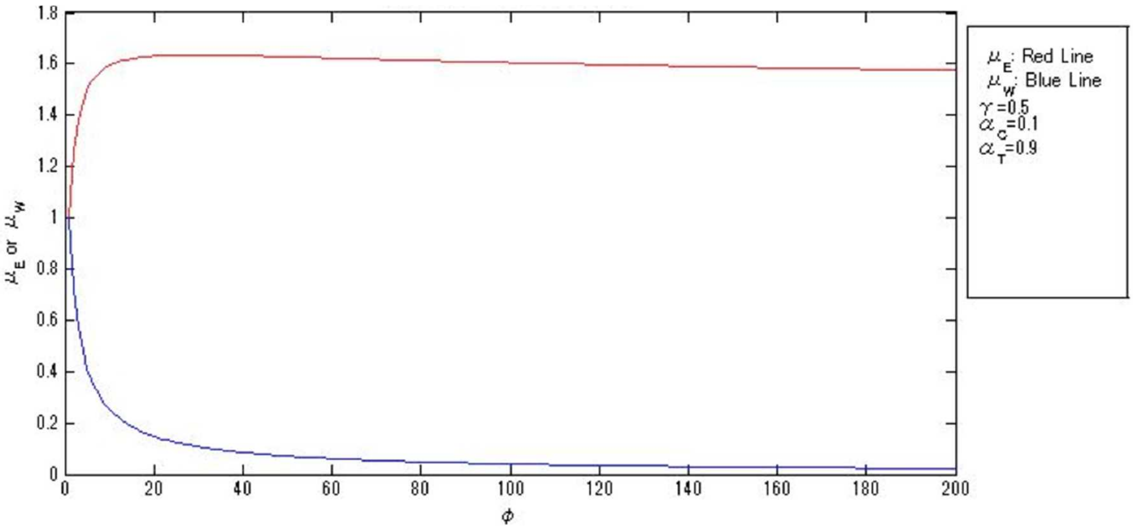

Fig. 3.2 The relationship between φ, μ_E and μ_W

In addition, a special case occurs only in the capital-abundant region (Region *E*). When φ is beyond a critical level $\bar{\varphi}$, i.e., $\varphi \in (\bar{\varphi}, \infty)$, with the increase in φ, μ_E will gradually decease and finally approach $\frac{\gamma}{1-\gamma}$. The reason is that when the fixed capital continues to agglomerate in Region *E*, the interregional productivity gap brought about by the interregional fixed capital gap becomes bigger and bigger, all manufacturing activities of both industries will also agglomerate to Region E. In fact, in Equation (3.41), when $\varphi \to \infty$, $Y_E^C \to (1-\gamma)Y$ and $Y_E^T \to \gamma Y$, which means that when all fixed capital agglomerates in Region *E*, all manufacturing activities will also agglomerate there. Finally, when $\varphi \to \infty$, the index of manufacturing structure in Region *E* approaches to the consumer's expenditure share: $\frac{\gamma}{1-\gamma}$. At the same time, as Lemma (iii) implies, the index of manufacturing structure in Region *W* will approach to zero. That is, there will be no high-tech industries remaining there.

The main parts of this lemma and their meanings can be concluded in the following Proposition 2. Fig. 3.2 presents a simulation result about the relationship among φ, μ_E and μ_W, which is based on Equations (3.41) and (3.42).

Proposition 2 *The capital-abundant region has a manufacturing structure dominated by relatively more high-tech industries than that of the region with less capital. Within a certain range, larger fixed capital gap between the two regions will bring about larger manufacturing structure gap between them.*

In the usual Hechscher-Ohlin comparative advantage analysis, the industrial structure is caused by the factor endowment differences. In this paper, the industrial structure is caused both by the endogenous productivity gap and the endowment difference of fixed capital stock.

3.3.3 Empirical Evidence from China

To provide some evidence for the obtained propositions, here we present some regional data from China. We divide China into the Eastern Region and Western Region based on Fujita and Hu (2001). Table 3.2 showed that from 1978 to 2004, the fixed capital ratio of the Eastern to Western Regions kept on increasing. We use the Manufacture of Textiles to represent the low-tech industry and use the Manufacture of Communication Equipment, Computers and other Electric Equipment to represent the high-tech industry following the OECD classification.[35] To match the time period in

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[35] http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:High-tech_classification_of_manufacturing_industries (Checked on 2018.09.27).

Table 3.2, we calculate the regional manufacturing structures of the two regions for the years of 1987, 1992, 1997, 2002 and 2006,[36] which are given by Table 3.4.

Table 3.4 Regional manufacturing structures in China

	1987	1992	1997	2002	2006
Ele.E /Tex.E (Standardized): μ_E	1.05	1.06	1.17	1.11	1.12
Ele.W /Tex.W (Standardized): μ_W	0.81	0.81	0.53	0.48	0.31
Ele .E/ Ele .W	3.07	3.87	6.06	11.8	21.29
Tex.E/Tex.W	2.27	2.95	2.8	4.95	5.93
$\varphi = (K_E/K_E)$	1.01	1.27	1.67	1.82	1.88

Source: calculated by the authors[37]

Ele.E: the nominal revenue of the manufacture of communication equipment, computers and other electric equipment (Ele industry afterwards) in the eastern provinces (The eastern provinces are defined below Table 1)

Tex.E: the nominal revenue of the manufacture of textile (Tex industry afterwards) in the eastern provinces

Ele.W: the nominal revenue of Ele industry in the western provinces (The western provinces are defined below Table 1)

Tex.W: the nominal revenue of Tex industry in the western provinces

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[36] Each statistical year of fixed capital stock is matched to the closet statistical year of the Industry Statistical Yearbook with a two-year advance. For example, regional fixed capital amounts data in the year of 1985 is matched to regional manufacturing structures data in the year of 1987. Considering the time lag between the change in regional fixed capital and the change in manufacturing structure, this matching approach is reasonable.

[37] Data Source: China Industry Statistical Yearbook (1988, 1993, 1998, 2003, 2007).

Ele.E /Tex.E (Standardized): the nominal revenue ratio of Ele.E to Tex.E, divided by the nominal revenue ratio of Ele industry to Tex industry of the whole China (Corresponding to μ_E in the last section)

Ele.W/ Tex.W (Standardized): the nominal revenue ratio of Ele.W to Tex.W, divided by the nominal revenue ratio of Ele industry to Tex industry of the whole China (Corresponding to μ_W in the last section)

Tex.E/Tex.W: the ratio of Tex industry in the eastern provinces to that in western provinces

Ele.E/ Ele.W: the ratio of Ele industry in the eastern provinces to that in the western provinces

From the second row in Table 4, we can see that from 1987 to 2006, in the capital-abundant Eastern Region, the standardized ratios of the high-tech to low-tech industries were always larger than 1, which implies that the high-tech industry dominated the regional manufacturing structure[38]. On the contrary, from the third row, we observe that the Western Region with less fixed capital has such a local manufacturing structure that is dominated by the low-tech industry. These facts are corresponding to Lemma (i).

From the second row, we can also see that in the Eastern Region, as the interregional fixed capital gap was increasing (see the last row), the standardized ratio of the high-tech to low-tech industries increased at first, then turned to decrease toward the ratio of the whole China. This finding is consistent with Lemma (ii).

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[38] If the industrial structure (the ratio of Ele.E to Tex.E) of the Eastern Region is similar to that of the whole China, μ_E will be one. If the region has a larger (smaller) ratio of Ele. E to Tex. E compared to that of the whole China, μ_E will be larger (smaller) than one.

From the third row, we can observe that in the Western Region, as the interregional fixed capital gap was increasing, the standardized ratio of the high-tech to low-tech industries kept on decreasing, which has been suggested by Lemma (iii).

Moreover, the fourth and fifth rows show that the capital-abundant eastern region had a larger nominal revenue of both the high-tech and low-tech industries, which is consistent with Proposition 1 that the capital-abundant region has an absolute advantage in both the high-tech and low-tech industries. It can also be found that the interregional revenue difference of the high-tech industry is larger than that of the low-tech industry, which supports our assumption that the high-tech industry has a stronger linkage with the local variety of intermediate goods and benefits more from it than does the low-tech industry.

Hu (2002, pp. 315-316) showed that trade and FDI have played more and more important roles in the Chinese economy in the period of 1980-1994, e.g. the ratio of trade volume to GDP increased from 15% in 1980 to nearly 45% in 1994, export of manufactured goods shows a strong and steadily increasing trend, FDI surged after 1990 and accounted for 15% of the total investment in fixed assets. He also highlighted that the uneven distribution of trade is associated with the uneven distribution of FDI over regions, e.g. in 1994, exports from the 12 coastal provinces accounted for 86% of China’s total export value, and from 1984 to 1994, more than 90% of total FDI inflow went to the coast.

Because that the formation of such regional manufacturing structures has not been modeled and investigated in the previous NEG literature, Propositions 1 and 2 could be considered as a contribution to the NEG literature.

3.4 Spatial Distribution of Labor

To date, we have investigated the formation of regional comparative advantage and manufacturing structures. However, the spatial distribution of labor remains to be examined.

We denote λ as the ratio of the labor amount in Region E to that in Region W, i.e., $\lambda \equiv \mathrm{L}_E/\mathrm{L}_W$, which presents the spatial distribution of labor in equilibrium. Differing from the traditional NEG models in which the variety of consumption goods and transportation costs are major considerations in the analysis of the spatial distribution of labor, we focus on the role of the local fixed capital, which determines the local labor productivity.

First of all, we examine the wages in Region E, denoted by ω_E. According to Equation (3.17), the total wage payment in Region W can be written as:

$$L_E\omega_E = \frac{(\sigma-\alpha_C)}{\sigma}Y_E^C + \frac{(\sigma-\alpha_T)}{\sigma}Y_E^T \tag{3.43}$$

Similarly, the total wage payment in Region W, denoted as ω_W, can be expressed as follows:

$$L_W\omega_W = \frac{(\sigma-\alpha_C)}{\sigma}Y_W^C + \frac{(\sigma-\alpha_T)}{\sigma}Y_W^T \tag{3.44}$$

Due to the equal capital rental interest and the equal prices of final goods across regions (since the trade of final goods incur no transportation costs), the local wages become the only consideration when laborers decide on their location. In equilibrium, there are equal wages across regions, i.e., $\omega_E = \omega_W = \omega$. Then, Equations (3.43) and (3.44) yield

$$\lambda \equiv \mathrm{L}_E/\mathrm{L}_W = \frac{\frac{(\sigma-\alpha_C)}{\sigma}Y_E^C + \frac{(\sigma-\alpha_T)}{\sigma}Y_E^T}{\frac{(\sigma-\alpha_C)}{\sigma}Y_W^C + \frac{(\sigma-\alpha_T)}{\sigma}Y_W^T} \tag{3.45}$$

Substituting Equations (3.37), (3.38), (3.39) and (3.40) into Equation (3.45), we obtain:

$$\lambda \equiv \mathrm{L}_E/\mathrm{L}_W = \frac{\frac{(\sigma-\alpha_C)}{\sigma}\frac{(1-\gamma)}{(1+\varphi^{-\alpha_C})} + \frac{(\sigma-\alpha_T)}{\sigma}\frac{\gamma}{(1+\varphi^{-\alpha_T})}}{\frac{(\sigma-\alpha_C)}{\sigma}\frac{(1-\gamma)}{(1+\varphi^{\alpha_C})} + \frac{(\sigma-\alpha_T)}{\sigma}\frac{\gamma}{(1+\varphi^{\alpha_T})}} \tag{3.46}$$

Regarding Equation (3.46), we know that $0 < \alpha_C < \alpha_T < 1,\ 0 < \gamma < 1, \sigma > 1$ and φ >1. So, $\frac{(\sigma-\alpha_C)}{\sigma}$>0, $\frac{(\sigma-\alpha_T)}{\sigma} > 0$ and $\frac{(1-\gamma)}{1+\varphi^{-\alpha_C}} > \frac{(1-\gamma)}{1+\varphi^{\alpha_C}} > 0, \frac{(1-\gamma)}{1+\varphi^{-\alpha_T}} > \frac{(1-\gamma)}{1+\varphi^{\alpha_T}} > 0$, which leads to $\frac{(\sigma-\alpha_C)}{\sigma}\frac{(1-\gamma)}{(1+\varphi^{-\alpha_C})} > \frac{(\sigma-\alpha_C)}{\sigma}\frac{(1-\gamma)}{(1+\varphi^{\alpha_C})} > 0$and $\frac{(\sigma-\alpha_T)}{\sigma}\frac{\gamma}{(1+\varphi^{-\alpha_T})} > \frac{(\sigma-\alpha_T)}{\sigma}\frac{\gamma}{(1+\varphi^{\alpha_T})} > 0$, therefore $\frac{(\sigma-\alpha_C)}{\sigma}\frac{(1-\gamma)}{(1+\varphi^{-\alpha_C})} + \frac{(\sigma-\alpha_T)}{\sigma}\frac{\gamma}{(1+\varphi^{-\alpha_T})} > \frac{(\sigma-\alpha_C)}{\sigma}\frac{(1-\gamma)}{(1+\varphi^{\alpha_C})} + \frac{(\sigma-\alpha_T)}{\sigma}\frac{\gamma}{(1+\varphi^{\alpha_T})}$>0. That is, $\lambda > 1$.

Examining (3.45), we can see that the spatial distribution of labor is associated with the revenues of the two industries in the two regions ($Y_E^C, Y_E^T, Y_w^C, Y_W^T$). The shares of labor payments in the two industries are constant (which are $\frac{(\sigma-\alpha_T)}{\sigma}$ and $\frac{(\sigma-\alpha_C)}{\sigma}$ of the high-tech and low-tech industries, respectively). And, the revenue of each industry in each region depends on the spatial distribution of fixed capital stock. In fact, from

Equations (3.37), (3.38), (3.39) and (3.40), we have $\frac{dY_E^C}{d\varphi} > 0, \frac{dY_E^T}{d\varphi} > 0; \frac{dY_W^C}{d\varphi} < 0, \frac{dY_W^T}{d\varphi} < 0$. So, we can obtain $\frac{d\lambda}{d\varphi} > 0$, which means that λ increases with the increase in φ.

To conclude the above discussions on $\lambda > 1$ and $\frac{d\lambda}{d\varphi} > 0$, we can have the following proposition:

Proposition 3 *In the two-region economy considered, the majority of labor is located in the capital-abundant region, and the amount of labor in this region increases as the local fixed capital stock in it increases.*

Proposition 3 can be supported by the evidence from the spatial distribution of population in China. The rapid increase in fixed capital investment in the Eastern Region caused the agglomeration of manufacturing activities there (see Tables 1 and 4), which leads to the interregional migration of laborers from the Western Region to the Eastern Region. These facts are widely observed in the Chinese economy.

3.5 Conclusion

Concerning the fact that the main line of NEG study (Krugman 1991) fails to explain the formation of regional comparative advantage and manufacturing structures, in this paper, we extended a NTT model (Matsuyama 1996) to a two-region economy to answer the following questions. How does the regional variety of intermediate inputs (as reflected by the local fixed capital stock) relate to the regional productivity and production advantage? Under the free movement of labor, how are regional manufacturing structures formed?

Based on the present model, we drew the major conclusions as follows. First, the region with more fixed capital stock has an absolute advantage in both the high-tech and low-tech industries. It also has a comparative advantage in the high-tech industry, which uses the fixed capital more intensively. In contrast, the region with less fixed capital stock has no absolute advantage, but it has a comparative advantage in the labor-intensified low-tech industry. Second, the capital-abundant region has a manufacturing structure dominated by relatively more high-tech industries than that of the region with less fixed capital stock. With the exception that the fixed capital stock gap between the two regions is beyond a certain value, larger gap brings larger gap of manufacturing structures. Third, the majority of labor is located in the capital-abundant region, and the amount of local labor in this region increases as the local fixed capital stock in it increases.

The present paper indicated the importance of the local fixed capital stock in the formation of regional comparative advantage and manufacturing structures. So, in the real world, to develop high comparative advantage to attract manufacturing companies to locate in a region, we need to promote the construction and investment about the region's local infrastructure and other fixed capital stock. Meanwhile, to raise the level of a region's industrial structure, we should strengthen the local fixed capital stock so as to attract more and more high-tech industries to agglomerate to the region[39]. These are the main policy implications involved in the present theoretical analysis.

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[39] For example, in year 2000, to balance the economic growth and industrial structure between West and East region, Chinese government implemented the western development strategy which includes many infrastructure projects using large amounts of fixed capital investments, such as the

3.A Appendixes

3.A.1 Proof of Lemma (ii)

Regarding Equation (3.41), differentiating μ_E with respect to φ, we obtain:

$$\frac{d\mu_E}{d\varphi} = \frac{\gamma}{1-\gamma}\left(\frac{\alpha_T\varphi^{-\alpha_T-1}}{1+\varphi^{-\alpha_T}} * \frac{1+\varphi^{-\alpha_C}}{1+\varphi^{-\alpha_T}} - \frac{\alpha_C\varphi^{-\alpha_C-1}}{1+\varphi^{-\alpha_T}}\right. \tag{3A.1}$$

Multiplying $\frac{1-\gamma}{\gamma} * \frac{1+\varphi^{-\alpha_T}}{\alpha_T\varphi^{-\alpha_C-1}}$ to both sides of (3A.1) yields:

$$\frac{d\mu_E}{d\varphi} * \frac{1-\gamma}{\gamma} * \frac{1+\varphi^{-\alpha_T}}{\alpha_T\varphi^{-\alpha_C-1}} = \frac{\varphi^{\alpha_C-\alpha_T}+\varphi^{-\alpha_T}}{1+\varphi^{-\alpha_T}} - \frac{\alpha_C}{\alpha_T} \tag{3A.2}$$

We define the right side of (3A.2) as:

$$F(\varphi) = \frac{\varphi^{\alpha_C-\alpha_T}+\varphi^{-\alpha_T}}{1+\varphi^{-\alpha_T}} - \frac{\alpha_C}{\alpha_T} \tag{3A.3}$$

If $\varphi = 1,\ F(\varphi) = 1 - \frac{\alpha_C}{\alpha_T} > 0$, and when $\varphi \to \infty,\ F(\varphi) \to -\frac{\alpha_C}{\alpha_T} < 0$.

Furthermore, by differentiating (3A.3) with respect to φ we obtain:

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constructions of Qinghai-Tibet Railway, the Xiaowan hydropower station, the Xian and Chengdu airport et al.

$$F'(\varphi) = \frac{(\alpha_C-\alpha_T)\varphi^{\alpha_C-\alpha_T-1}-\alpha_T\varphi^{-\alpha_T-1}}{1+\varphi^{-\alpha_T}} + \frac{\alpha_T\varphi^{-\alpha_T-1}}{1+\varphi^{-\alpha_T}} * \frac{\varphi^{\alpha_C-\alpha_T}+\varphi^{-\alpha_T}}{1+\varphi^{-\alpha_T}} \qquad (3A.4)$$

$$=(\frac{\varphi^{\alpha_C-\alpha_T}+\varphi^{-\alpha_T}}{1+\varphi^{-\alpha_T}} - 1)\ \frac{\alpha_T\varphi^{-\alpha_T-1}}{1+\varphi^{-\alpha_T}} + \frac{(\alpha_C-\alpha_T)\varphi^{\alpha_C-\alpha_T-1}}{1+\varphi^{-\alpha_T}}$$

Given that $\alpha_C < \alpha_T$ and $\varphi > 1$, $F'(\varphi) < 0$. Since when $\varphi = 1$, $F(\varphi) > 0$; and for $\varphi \to \infty$, $F(\varphi) < 0$, we obtain that the solution of $F(\varphi) = 0$ is unique (denoted as $\bar{\varphi}$), and for any $\varphi \in (1, \bar{\varphi}), F(\varphi) > 0$ while for any $\varphi \in (\bar{\varphi}, \infty), F(\varphi) < 0$.

Since $\frac{1-\gamma}{\gamma} * \frac{1+\varphi^{-\alpha_T}}{\alpha_T\varphi^{-\alpha_C-1}}>0$, $\frac{d\mu_E}{d\varphi}$ has the same sign as $F(\varphi)$. That is, there is an unique solution, $\bar{\varphi}$, which satisfies $\frac{d\mu_E}{d\varphi} = 0$. For any $\varphi \in (\bar{\varphi}, \infty), \frac{d\mu_E}{d\varphi} > 0$, and for any $\varphi \in (1, \bar{\varphi}), \frac{d\mu_E}{d\varphi} < 0$. This also implies that there is an inverted U-shape relationship between μ_E and φ.

When $\varphi \to \infty$, $\varphi^{-\alpha_C} \to 0$ and $\varphi^{-\alpha_T} \to 0$. Thus using Equation (3.41), $\mu_E = \frac{\gamma}{1-\gamma} * \frac{1+\varphi^{-\alpha_C}}{1+\varphi^{-\alpha_T}} \to \frac{\gamma}{1-\gamma}$.

Q.E.D.

3.A.2 Proof of Lemma (iii)

Regarding Equation (3.42), differentiating μ_W with respect to φ, we obtain:

$$\frac{d\mu_W}{d\varphi} = \frac{\gamma}{1-\gamma}(\frac{\alpha_C\varphi^{\alpha_C-1}}{1+\varphi^{\alpha_T}} - \frac{\alpha_T\varphi^{\alpha_T-1}}{1+\varphi^{\alpha_T}} * \frac{1+\varphi^{\alpha_C}}{1+\varphi^{\alpha_T}}) \qquad (3.A.5)$$

Multiplying $\frac{1-\gamma}{\gamma} * \frac{1+\varphi^{\alpha_T}}{\alpha_T\varphi^{\alpha_C-1}}$ to both sides of (3A.5) yields:

$$\frac{d\mu_W}{d\varphi} * \frac{1-\gamma}{\gamma} * \frac{1+\varphi^{\alpha_T}}{\alpha_T \varphi^{\alpha_C - 1}} = \frac{\alpha_C}{\alpha_T} - \frac{\varphi^{\alpha_T - \alpha_C} + \varphi^{\alpha_T}}{1+\varphi^{\alpha_T}} \tag{3A.6}$$

Given that $\varphi > 1$ and $\alpha_T > \alpha_C$, we have $\frac{\alpha_C}{\alpha_T} < 1$ and $\frac{\varphi^{\alpha_T - \alpha_C} + \varphi^{\alpha_T}}{1+\varphi^{\alpha_T}}$>1. Then, $\frac{\alpha_C}{\alpha_T} - \frac{\varphi^{\alpha_T - \alpha_C} + \varphi^{\alpha_T}}{1+\varphi^{\alpha_T}} < 0$, which means

$$\frac{d\mu_W}{d\varphi} * \frac{1-\gamma}{\gamma} * \frac{1+\varphi^{\alpha_T}}{\alpha_T \varphi^{\alpha_C - 1}} < 0 \tag{3A.7}$$

Since $\frac{1-\gamma}{\gamma} * \frac{1+\varphi^{\alpha_T}}{\alpha_T \varphi^{\alpha_C - 1}}$ > 0, we have $\frac{d\mu_W}{d\varphi} < 0$.

When $\varphi \to \infty$, $1 + \varphi^{\alpha_C} \to \varphi^{\alpha_C}$, $1 + \varphi^{\alpha_T} \to \varphi^{\alpha_T}$ and $\frac{\varphi^{\alpha_C}}{\varphi^{\alpha_T}} \to 0$. So, using Equation (3.42) we have $\mu_W = \frac{\gamma}{1-\gamma} * \frac{1+\varphi^{\alpha_C}}{1+\varphi^{\alpha_T}} \to \frac{\gamma}{1-\gamma} * \frac{\varphi^{\alpha_C}}{\varphi^{\alpha_T}} \to 0$.

Q.E.D.

Chapter 4

Urban Agglomeration and Industrial Upgrading

4.1 Introduction

It is well know that industrial upgrading plays a critical role in economic growth. As Schumpeter (1942, pp.82-83) noted,

> “The essential point to grasp is that in dealing with capitalism we are dealing with an evolutionary process…. The fundamental impulse that sets and keeps the capitalist engine in motion comes from the new consumers’ goods, the new forms of industrial organization that capitalist enterprise create.”

Aghion and Howitt (1990) and Grossman and Helpman (1991) modeled Schumpeter's process of creative destruction. Ozawa (2005) further empirically studied the process of creative destruction and proposed the “leading-growth sector stages” theory along the lines of Schumpeter, in which a sequence of growth is punctuated by stages in the wake of the “perennial gale of creative destruction”. In each stage, a certain industrial sector can be identified as the main engine of structural transformation enabling the economy to scale the ladder of industrial development.

However, the abovementioned theories fail to consider the effect of spatial distribution of economic activities on industrial upgrading, despite the fact that the role of urban agglomerations in industrial upgrading has been discussed for a long time (Jacob, 1969; Moretti, 2012).

Jacob (1969, pp.1-48) illustrated that new production activities are generally bred in urban agglomerations and are then transplanted from agglomerations to the peripheries, thereby highlighting the role of urban agglomerations in the nursery of innovations. Through a comparison between traditional manufacturing cities and cities dominated by high-tech industries, Moretti (2012) demonstrated that the growth or decline of a city lies in whether it can upgrade its industrial structure. He also noted that it is hard to predict which city will experience industrial upgrading.

Unfortunately, the majority of the models of urban system fail to analyze the industrial composition in cities. For example, the famous model of urban system (Henderson, 1974) assumed that a firm enjoys positive externalities from only the intra-industry spatial concentration of economic activities, so each city specializes only in one industry. That framework cogently explained the urban productivity premium. It is, however, ill-suited to explain the formation of urban industrial composition[40]. Indeed, some other models of urban system do have taken the production diversity into consideration. Abdel-Rahman and Fujita (1993) introduced inter-industry agglomeration economies into the Henderson (1974) model, illustrating that if intra-industry agglomeration economies[41] dominate the inter-industry agglomeration economies, cities will specialize, if not, they will diversify. Anas and Xiong (2003) further considered the trade costs of manufactures and services, theoretically showing that a lower cost of trading manufactures favors a system of specialized cities, while a high cost of trading services favors a system of diversified cities. However, these

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[40] In another vein of regional economics, Fujita et al. (1999, pp.181-213) extended the canonical New Economic Geography model of Krugman (1991) to a "hierarchical urban system", which shows that a city with a larger size does everything a smaller city does, and more. However, their model focuses on the inter-city interaction and does not take account of internal city structure when dealing with city systems.

[41] Generally, the intra- and inter-industry externalities are called localization economies and urbanization economies, respectively (See Rosenthal and Strange (2004) for a literature review).

models have overwhelmingly described sectoral composition in polarized terms, as noted in Abdel-Rahman and Anas (2004, p.2313) as follows,

> "If a city contains only one industry, it is referred to as a specialized city; if it contains all of the modeled industries (or at least more than one), it is called a diversified city. All models of city system have either specialized or diversified cities."

In this sense, they lack the implications on the specific industrial compositions of cities, without answering the following question raised by Abdel-Rahman and Anas (2004, p.2313):

> "Are cities in the system identical in size and in industrial composition or are they different?"

As far as we know, the study of Davis and Dingel (2014) is the only exception that proposed a multi-sector linking urban sectoral composition to city size and skill composition. Specifically, their model assumed that the individual with higher skill is more productive in the sector with high skill-intensity (the productivity of an individual in a sector is log-supermodular in the individual's skill level and the sector's skill intensity), and hence a sector consists of only the individuals with a certain skill level corresponding to the sector's skill intensity. Then, with the existence of congestion costs, larger cities are skill-abundant and specialize in skill-intensive activities. However, this assumption does not correspond with the empirical findings in Henderics (2011), which showed that 80% of cross-city education gaps are due to within-industry variation and only the remaining 20% are due to industrial specialization. That is, each sector hires individuals with variant skill-levels. Moreover, in Davis and Dingel (2014), all sectors in a city are still assumed to be equally affected by common city-dependent agglomeration economies[42]. Regarding this assumption, however, many empirical studies have confirmed that high-tech industries benefit more from agglomeration economies.

For instance, Henderson et al. (1995) found that the diversity of manufacturing activities encourages growth for high-technology firms but not for machinery industries. Henderson (2003) showed that high-tech industries are more agglomerated than machinery industries and that the number of other plants in the same industry has strong effects on the productivity of high-tech but not machinery industries. Duranton and Puga (2001) showed that innovative industries (research and development (R&D), pharmaceuticals and cosmetics, information technology (IT), consultancy services, and business services) benefit most from urban diversity. Rosenthal and Strange (2003) observed that the magnitude of spillover effects in fabricated metal and machinery industries tends to be approximately only 20% of that in software industries. Porter (1998) argued that the effect of sharing specialized services is more significant in the fields of "advanced and specialized inputs involving embedded technology, information, and service content."

Given that high-tech industries use skilled labor, scientific research and education, and information and communications more intensively than low-tech industries, and that the major channels of agglomeration economies are labor pooling, knowledge spillovers and sharing in specialized services (Duranton and Puga, 2004), it is natural to infer that high-tech industries will rely on agglomeration economies more intensively.

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[42] In their model, city-dependent agglomeration economies (reflected by the total employment in the city) are embedded in production functions as a common multiplier; therefore, the elasticity of city size to productivity is equal across all economic sectors with different skill intensities.

In this regard, in light of Davis and Dingel (2014), this paper characterizes industries according to their dependence on agglomeration economies.

Specifically, Section 4.2 introduces two industries and the industry-specific agglomeration economies into the Henderson model of urban system (1974) to show that cities with larger scale of employment have comparative advantages and specialize in the production of high-tech goods.

To verify the theoretical propositions, Subsection 4.3 develops an industrial stage index for each industry based on its employment share of engineers, administrative and managerial workers, its input coefficient of scientific research and education, and its input coefficient of information and communications. It then builds an urban industrial stage index for a city based on the city's employment composition and the developed industrial stage index. Regarding this index, we propose some regression equations using the theoretical model, and provide the estimated results and the related interpretations in Section 4.4. Finally, we conclude the paper in Section4. 5.

4.2 A Two-Industry Model of Urban System

Like Henderson (1974), we consider a closed economy with cities where a exogenously given number of national households are free to live in any city. In each city, two tradable goods—high-tech and low-tech goods—are produced, which is different from Henderson (1974). The production of the high-tech goods is supposed to depend on agglomeration economies more intensively than does the production of the low-tech goods. It is also assumed that each household consumes a fixed unit of land and is endowed with one unit of time. Labor supplied by households (net of deductions for the communication costs[43]) is the only production factor, and the wage of labor is equal across industries (because of the homogenous labor).

Each industry consists of homogenous production firms and each firm produces one kind of tradable goods using agglomeration economies that are external to the firm but internal to the city in which it is located[44]. Under this externality specification, each firm views itself as having a production function with constant returns to scale, which ensures the perfect competition[45].

In a city, denoted by *i*, the production activities of individual firms can be represented by the following aggregate production functions for the two industries:

$$HT_i = A_{HTi}L_{HTi} \tag{4.1}$$

$$LT_i = A_{LTi}L_{LTi} \tag{4.2}$$

$$A_{HTi} = R_{HTi}{L_i}^{\alpha_{HT}} \tag{4.3}$$

$$A_{LTi} = R_{LTi}{L_i}^{\alpha_{LT}} \tag{4.4}$$

$$\alpha_{HT} > \alpha_{LT} > 0 \tag{4.5}$$

where L_i is the aggregate labor supply or total employment in the city. L_{HTi} (L_{LTi}) is the amount of labor inputted in the high-tech (low-tech) industry in city *i*. Thus, $L_{HTi} + L_{LTi} = L_i$. HT_i (LT_i) is the amount of high-tech (low-tech) goods produced in city *i*. A_{HTi} (A_{LTi}) represents the labor productivity of the high-tech (low-tech) industry. R_{HTi} (R_{LTi}) is the exogenous first nature of city *i* for the high-tech (low-tech) industry[46].

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[43] See Abdel-Rahman and Anas (2004).

[44] See Chipman (1970) and Henderson (1974).

[45] See Chipman (1970, pp. 347-350).

[46] Gonzalez-Val and Pueyo (2010) defined first nature as follows: “There are many factors influencing the distribution of economic activity. It is traditional to distinguish between

Equations (4.3) and (4.4) imply the agglomeration economies (see Duranton and Puga (2004) regarding the micro economic foundations of agglomeration economies), where α_{HT} (α_{LT}) is the intensity of agglomeration economies used in the high-tech (low-tech) industry. In particular, we impose an important assumption that $\alpha_{HT} > \alpha_{LT} > 0$. That is, the high-tech industry benefits more from agglomeration economies than does the low-tech industry.

Since labor is movable across industries, the wage of labor of city i (W_i) will be equal across the two industries, that is:

$$W_{HTi} = W_{LTi} = W_i \tag{4.6}$$

where $W_{HTi}(W_{LTi})$ is the wage of the high-tech (low-tech) industry in city i. From Equations (4.1), (4.2), (4.3) and (4.4), the average production cost of the high-tech goods, denoted by C_{HTi}, and that of the low-tech goods, denoted by C_{LTi}, can be expressed as:

$$C_{HTi} = \frac{W_i}{R_{HTi}{L_i}^{\alpha_{HT}}} \tag{4.7}$$

$$C_{LTi} = \frac{W_i}{R_{LTi}{L_i}^{\alpha_{LT}}} \tag{4.8}$$

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characteristics linked to the physical landscape, such as temperature, rainfall, access to the sea, the presence of natural resources or the availability of arable land, and factors relating to human actions and economic incentives (for example, scale economies or knowledge spillovers). The first group of factors, related to natural geographical circumstances, are called 'first nature causes', and the second group are called 'second nature causes'." Their definition is close to the meaning of first nature referred in this paper.

Furthermore, using Equations (4.7) and (4.8), the relative production cost of high-tech goods in terms of that of low-tech goods, denoted by C_{HLi}, can be written as:

$$C_{HLi} = \frac{C_{HTi}}{C_{LTi}} = \frac{R_{LTi}}{R_{HTi}} L_i^{\alpha_{LT}-\alpha_{HT}} \tag{4.9}$$

Differentiating Equation (4.9) with respect to L_i yields $\frac{d(C_{HLi})}{d(L_i)} < 0$, which means that the relative production cost of high-tech goods in terms of that of low-tech goods increases with the city's total employment. Using the comparative advantage theory (Ricardo, 1817), we obtain the following proposition:

Proposition 1 *The more(less) total employment a city has, the larger comparative advantage it will have in the high-tech (low-tech) industry.*

Next, we turn to analyze the consumption. Suppose that every household (consumer) shares the same utility function as follows:

$$U = [\left(\sum_{j=1}^{M} HT_j^{\frac{\sigma}{\sigma-1}}\right)^{\frac{\sigma-1}{\sigma}}]^{\gamma}[(\sum_{j=1}^{M} LT_j^{\frac{\sigma}{\sigma-1}})^{\frac{\sigma-1}{\sigma}}]^{1-\gamma},\ 0 < \gamma < 1 \text{ and } \sigma > 1 \tag{4.10}$$

where HT_j (LT_j) is the consumption amount of high-tech (low-tech) goods produced in city j. γ is the expenditure share of high-tech goods of the consumer, and $1-\gamma$ is that of the low-tech goods. Furthermore, we assume that every household (consumer) has the Armington (1969) type of constant elasticity of substitution (CES) sub-utility function about the two goods. That is, each city produces a differentiated high-tech good and a differentiated low-tech good[47]. σ (>1) represents the elasticity of substitution between any pair of high-tech (low-tech) goods produced in different cities (the elasticity of substitution among high-tech goods is assumed to be equal to that among low-tech goods).

Household's problem of city *i* is to maximize the utility function subject to a budget constraint, which can be expressed as follows:

$$\text{Max} U_i = [\left(\sum_{j=1}^{M} HT_{ji}{}^{\frac{\sigma}{\sigma-1}}\right)^{\frac{\sigma-1}{\sigma}}]^{\gamma}[(\sum_{j=1}^{M} LT_{ji}{}^{\frac{\sigma}{\sigma-1}})^{\frac{\sigma-1}{\sigma}}]^{1-\gamma}$$

$$\text{s.t. } Y_i = \sum_{j=1}^{M} HT_{ji}P_{HTji} + \sum_{i=1}^{M} LT_{ji}P_{LTji} \qquad (4.11)$$

where Y_i is the aggregate disposable income or total expenditure of city *i*. HT_{ji} (LT_{ji}) is city *i*'s consumption amount of the high-tech (low-tech) goods produced in city *j*. P_{HTji} (P_{LTji}) is the price of high-tech (low-tech) goods produced in city *j* and sold in city *i*.

Suppose that intercity transport costs take the iceberg form (Krugman, 1991). That is, when transporting one unit of high-tech (low-tech) goods from city *i* to city *j*, only a fraction τ_{HTij} (τ_{LTij}) of them arrive, while the rest "melt" during the transporting. So, the price of high-tech (low-tech) goods produced in city *j* and sold in city *i* can be written as:

$$P_{HTji} = P_{HTjj}\,\tau_{HTji},\ 0 < \tau_{HTji} < 1 \text{ and } \tau_{HTii} = 0 \qquad (4.12)$$

$$P_{LTji} = P_{LTjj}\,\tau_{LTji},\ 0 < \tau_{HTji} < 1 \text{ and } \tau_{LTii} = 0 \qquad (4.13)$$

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[47] The Armington (1969) assumption is widely used in New Trade Theory, New Economic Geography, and urban systems models. See Overman, Redding and Venables (2003) and Head and Mayer (2004) for reviews.

Using Equations (4.12) and (4.13), we can see that the first order condition of the maximization problem (4.11) yields city *i*'s demand amounts for the high-tech goods and the low-tech goods produced in city *j* as follows, respectively:

$$HT_{ji} = (P_{HTjj}\,\tau_{HTji})^{-\sigma}\gamma Y_i {G_{HTi}}^{\sigma-1} \tag{4.14}$$

$$LT_{ji} = (P_{LTjj}\,\tau_{LTji})^{-\sigma}(1-\gamma) Y_i {G_{LTi}}^{\sigma-1} \tag{4.15}$$

where G_{HTi} (G_{LTi}) is the price index of high-tech (low-tech) goods sold in city *i,* which can be written as follows:

$$G_{HTi} = [\textstyle\sum_{j=1}^{M} (P_{HTjj}\,\tau_{HTji})^{1-\sigma}]^{\frac{1}{1-\sigma}} \tag{4.16}$$

$$G_{LTi} = [\textstyle\sum_{j=1}^{M} P_{LTjj}\,\tau_{LTji})^{1-\sigma}]^{\frac{1}{1-\sigma}} \tag{4.17}$$

where P_{HTjj} (P_{LTjj}) is the price of high-tech (low-tech) goods produced in city *j* and sold locally. Under the perfect competition, the prices equal the local production cost of the high-tech (low-tech) goods, respectively. So, from Equation (4.7) (Equation (4.8)), P_{HTjj} (P_{LTjj}) can be expressed as follows:

$$P_{HTjj} = C_{HTj} = \frac{w_j}{R_{HTj}{L_j}^{\alpha_{HT}}} \tag{4.18}$$

$$P_{LTjj} = C_{LTj} = \frac{w_j}{R_{LTj}{L_j}^{\alpha_{LT}}} \tag{4.19}$$

Substituting Equation (4.18) into Equation (4.16) yields:

$$G_{HTi} = [\textstyle\sum_{j=1}^{M} \left(\tau_{HTji} \frac{W_j}{R_{HTj} {L_j}^{\alpha_{HT}}} \right)^{1-\sigma}]^{\frac{1}{1-\sigma}} \tag{4.20}$$

Similarly, substituting Equation (4.19) into Equation (4.17) yields:

$$G_{LTi} = [\textstyle\sum_{j=1}^{M} \left(\tau_{LTji} \frac{W_j}{R_{LTj} {L_j}^{\alpha_{HT}}} \right)^{1-\sigma}]^{\frac{1}{1-\sigma}} \tag{4.21}$$

Multiplying the demand amounts ((4.14) and (4.15)) by the corresponding prices ((4.12) and (4.13)) yields city *i*'s nominal demand amounts for the two goods produced in city *j*, which can be expressed as follows, respectively:

$$Y_{HTji} = \gamma(\tau_{HTji} P_{HTjj})^{1-\sigma} {G_{HTi}}^{\sigma-1}\ \mathrm{Y}_i \tag{4.22}$$

$$Y_{LTji} = (1-\gamma)(\tau_{LTji} P_{LTjj})^{1-\sigma} {G_{LTi}}^{\sigma-1}\ \mathrm{Y}_i \tag{4.23}$$

where Y_{HTji} (Y_{LTji}) is city *i*'s nominal demand for the high-tech (low-tech) goods produced in city *j*.

Aggregating each city's nominal demands for the high-tech goods produced in city *j* (Equation (4.22)) yields the aggregate nominal demand for the high-tech goods produced in city *j* (or the total revenue of the high-tech industry in city *j*), denoted as Y_{HTj}, as follows:

$$Y_{\mathrm{HT}j} = \textstyle\sum_{i=1}^{M} \gamma(\tau_{HTji} P_{HTjj})^{1-\sigma} {G_{HTi}}^{\sigma-1}\ \mathrm{Y}_i) = \gamma {P_{HTjj}}^{1-\sigma} \sum_{i=1}^{M} ({G_{HTi}}^{\sigma-1} {\tau_{HTji}}^{1-\sigma}\ \mathrm{Y}_i) \tag{4.24}$$

Similarly, the aggregate nominal demand for the low-tech goods produced in city j (or the total revenue of high-tech industry in city j), denoted as Y_{LTj}, can be obtained as:

$$Y_{LTj} = (1-\gamma)P_{LTjj}^{\;1-\sigma} \sum_{i=1}^{M}(G_{LTi}^{\;\sigma-1}\, \tau_{LTji}^{\;1-\sigma}\, \mathrm{Y}_i) \tag{4.25}$$

Using Equations (4.24) and (4.25), the industrial composition in city j can be expressed as follows:

$$\frac{Y_{HTj}}{Y_{LTj}} = \frac{\gamma}{1-\gamma}\left(\frac{P_{HTjj}}{P_{LTjj}}\right)^{1-\sigma}\frac{FMA_{HTj}}{FMA_{LTj}} \tag{4.26}$$

where $FMA_{HTj} \equiv \sum_{j=1}^{M}(G_{HTi}^{\;\sigma-1}\tau_{HTji}^{\;1-\sigma}\, \mathrm{Y}_i)$ and $FMA_{LTj} \equiv \sum_{j=1}^{M}(G_{LTi}^{\;\sigma-1}\, \tau_{LTji}^{\;1-\sigma}\, \mathrm{Y}_i)$, which are city j's firm market accesses of the high-tech industry and the low-tech industry, respectively[48]. Due to the perfect competition, each industry's total revenue equals its total labor payment. Additionally, recall that labor wages are equal across industries. So, in city j, the total revenue ratio of the high-tech and low-tech industries equals the employment ratio of them, that is:

$$\frac{L_{HTj}}{L_{LTj}} = \frac{Y_{HTj}}{Y_{LTj}} = \frac{\gamma}{1-\gamma}\left(\frac{P_{HTjj}}{P_{LTjj}}\right)^{1-\sigma}\frac{FMA_{HTj}}{FMA_{LTj}} \tag{4.27}$$

Substituting the local prices, expressed by Equations (4.18) and (4.19), into (4.27), the employment ratio of the high-tech and low-tech industries can be given as follows:

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[48] The expression of firm market access is drawn from Redding and Sturn (2008, p.1772).

$$\frac{L_{HTj}}{L_{LTj}} = \frac{\gamma}{1-\gamma}\left(\frac{R_{LTj}}{R_{HTj}} L_j{}^{\alpha_{LT}-\alpha_{HT}}\right)^{1-\sigma} \frac{FMA_{HTj}}{FMA_{LTj}} \tag{4.28}$$

Equation (4.28) can be further manipulated to yield the following share of the high-tech industry in the total employment of the city:

$$\frac{L_{HTj}}{L_j} = \frac{L_{HTj}}{L_{HTj}+L_{LTj}} = \frac{\frac{\gamma}{1-\gamma}\left(\frac{R_{LTj}}{R_{HTj}} L_j{}^{\alpha_{LT}-\alpha_{HT}}\right)^{1-\sigma}\frac{FMA_{HTj}}{FMA_{LTj}}}{\frac{\gamma}{1-\gamma}\left(\frac{R_{LTj}}{R_{HTj}} L_j{}^{\alpha_{LT}-\alpha_{HT}}\right)^{1-\sigma}\frac{FMA_{HTj}}{FMA_{LTj}}+1} \tag{4.29}$$

Given that $\alpha_{LT} - \alpha_{HT} < 0$ and $1 - \sigma < 0$, we can prove that $\frac{d(\frac{L_{HTj}}{L_j})}{dL_j} > 0$. So we obtain the following proposition.

Proposition 2. *Given the first nature and firm market accesses for the high-tech and low-tech industries, the more total employment a city has, the larger employment share the high-tech industry will have.*

In the model of Davis and Dingel (2014), it is shown that the land price of a location in a larger city is higher than that of a similar location (e.g., with similar distance to CBD) in a smaller city. Since the higher land price must be compensated for by the saving of commuting cost (in proportion to the distance to CBD and the skill-specific wage), the labor in a larger city will have a higher skill level than the labor locating in a similar location in a smaller city. That is, large cities will have a *factor-driven comparative advantage in skill-intensive industries*. Different from their model, this paper focuses on the role of the agglomeration economies. So, we show that the city with a larger total employment will be more attractive to the high-tech industries, which depend more intensively on agglomeration economies. The clarification of the relationship between urban agglomeration and the level of industrial upgrading can be considered a contribution to the literature of urban economics.

4.3 Data and Estimation Methods

4.3.1 The Industrial Stage Index and Urban Industrial Stage Index

To empirically verify Proposition 2, we need to quantify the employment share of high-tech activities in cities. In this regard, we first quantify the industrial stage for these activities.

To compile statistics on high-tech activities, EU uses the index of *technological intensity* (R&D expenditure/value added)[49] to classify manufacturing industries of low-technology and high-technology. However, this classification has the following two defects. (a) Besides the R&D expenditure, input intensities regarding skilled labor and IT are also important in the industrial upgrading and should be considered in the evaluation of an industry's industrial stage. *OECD Science, Technology and Innovation Outlook 2016* showed that IT industries have a significant influence on the modern global economy. Ozawa (2005) and Baumol (2002) noted that modern economic growth was driven by the IT-related industries. In addition, Moretti (2012) accentuated the role of human capital in urban industrial upgrading. For these reasons, the input intensities regarding information and communications and skilled labor should be taken into

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[49] See http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:High-tech_classification_of_manufacturing_industries

consideration. (b) EU only classifies manufacturing industries, without the consideration of service industries. In fact, service industries account for the largest proportion in the modern global economy, especially in urban areas. In this sense, service industries should be included in the evaluation of urban industrial upgrading. In this regard, this paper develops an industrial stage index for two-digit industries (including agriculture industries and service industries) using the following three factors, (i) input intensity of scientific research and education, (ii) input intensity of information and communications, and (iii) employment shares of engineers, administrative and managerial workers. The three components of the industrial stage index also correspond to the well-known three channels of agglomeration economies, i.e., knowledge spillover, sharing of specialized service and labor pooling. Thai is, high-tech industries benefit more from agglomeration economies.

Specifically, to define the industrial stage index (IS_k) for industry *k*, we average the standardized values of its employment share of engineers, administrative and managerial workers, its input coefficient of scientific research and education, and its input coefficient of information and communications[50]. Specifically, the industrial stage index (IS_k) is constituted as follows:

$$IS_k = (\frac{R\&D_k}{\overline{R\&D}} + \frac{IT_k}{\overline{IT}} + \frac{SL_k}{\overline{SL}})/3 \qquad (4.30)$$

where $R\&D_k$ is the input coefficient of education and scientific research of industry *k*; IT_k is the input coefficient of information and communications, and SL_k is the employment share of engineers, administrative and managerial workers of the industry.

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[50] The industrial classification and input coefficients are based on the Input-Output Tables for Japan (2011).

$\overline{R\&D}$, $\overline{I\&C}$, and $\overline{SL}$ are the averages of these coefficients and shares of all industries. That is, $\overline{R\&D}=\frac{\sum_k R\&D_k}{35}$, $\overline{I\&C}=\frac{\sum_k I\&C_k}{35}$, $\overline{SL}=\frac{\sum_k SL_k}{35}$, where 35 is the total number of all industries. The data are collected from the 2014 Labor Force Survey for Japan and the Input-Output Tables for Japan (2011). The details of the industrial stage index calculated for these industries are given in Table 1.

Table 4.1 The details of the industrial stage index calculated for all industries

Names of industry	SL_k	$R\&D_k$	IT_k	IS_k
Information and communications	0.616	0.019	0.152	4.425
Manufacture of information and communication electronics equipment	0.286	0.072	0.022	2.324
Scientific research and education	0.733	0.003	0.024	2.126
Manufacture of chemical and allied products	0.197	0.080	0.012	2.073
Business services	0.219	0.003	0.072	1.820
Electronic parts, devices and electronic circuits	0.180	0.069	0.010	1.811
Manufacture of business oriented machinery	0.222	0.065	0.008	1.801
Manufacture of electrical machinery, equipment and supplies	0.188	0.057	0.013	1.663
Medical, health care and welfare	0.495	0.003	0.014	1.422
Manufacture of production machinery	0.171	0.036	0.011	1.208
Finance and insurance	0.058	0.001	0.059	1.197
Manufacture of transportation equipment	0.127	0.040	0.003	1.052
Manufacture of general-purpose machinery	0.143	0.026	0.008	0.926

Wholesale and retail trade	0.054	0.003	0.040	0.892
Manufacture of plastic and rubber products	0.079	0.024	0.006	0.715
Electricity, gas, heat supply	0.138	0.007	0.012	0.656
Manufacture of non-ferrous metals and products	0.125	0.016	0.004	0.639
Manufacture of ceramic, stone and clay products	0.065	0.020	0.007	0.630
Miscellaneous manufacturing industries	0.071	0.015	0.007	0.548
Manufacture of textile mill products	0.055	0.016	0.007	0.520
Personal services	0.039	0.001	0.020	0.456
Manufacture of fabricated metal products	0.064	0.009	0.006	0.416
Construction	0.095	0.002	0.009	0.407
Manufacture of pulp, paper and wood products	0.055	0.007	0.006	0.353
Mining	0.000	0.009	0.010	0.333
Real estate	0.105	0.000	0.004	0.309
Transport and postal activities	0.027	0.002	0.011	0.304
Manufacture of food and beverage	0.034	0.006	0.005	0.279
Waste disposal business	0.031	0.000	0.010	0.251
Manufacture of iron and steel	0.042	0.007	0.002	0.250
Agriculture, forestry and fisheries	0.009	0.001	0.003	0.096
Manufacture of petroleum and coal products	0.000	0.002	0.001	0.047

Notes: Industries are ranked based on the industrial stage index (IS_k).

Ozawa (2005, pp. 14-15) analyzed the process of industrial upgrading using the following five Tiers (Stages):

Tier I “Heckscher-Ohlin” endowment-driven industries (textiles) →

Tier II “nondifferentiated Smithian” scale-driven industries (steel and chemicals) → Tier III “differentiated Smithian” assembly-based industries (automobiles) → Tier IV “Schumpeterian R&D-driven industries” (microchips and computers) → Tier IV-A “McLuhan” internet-based industries (information).

The industrial stage index defined seems to well reflect Ozawa’s analysis. It is also in line with OECD classification of manufacturing industries in terms of low-tech and high-tech activities. In this regard, the industrial stage index developed in this paper can be considered an appropriate indicator that reflects intensity in high-tech activities.

With the calculated industrial stage index, we build an urban industrial stage index (UIS) by adding up the product of an industry’s employment share of a city and its industrial stage index to represent the city’s intensity in high-tech activities, which is written as follows:

$$UIS_i = \sum_k IS_k * ES_{ki} \tag{4.31}$$

where ES_{ki} is the employment share of industry *k* in city *i*. ES_{ki} means the value of $\frac{L_{ki}}{L_i}$, where L_{ki} is the employment amount of industry *k* in city *i*, and L_i is the total employment of city *i*. If a city specializes completely in the information and communications industry, it will be standing at the highest industrial stage, with the highest value of UIS equal to 4.425. In contrast, if a city specializes completely in the manufacturing of petroleum and coal products, it will remain at the lowest industrial stage, with the lowest value of UIS equal to 0.047 (See Table 1). Since the UIS reflects a city's employment share of high-tech activities, in the following subsection, it will be used as the dependent variable, corresponding to the term of $\frac{L_{HTi}}{L_i}$ in Equation (4.29).

In the exist literature, industrial structural transformation generally refers to the reallocation of economic activity across the broad sectors such as agriculture, manufacturing and services[51]. Although such reallocation coincides with the process of economic growth, it cannot reflect the technological upgrading very well[52]. As far as we know, this paper could be considered as the first attempt to explicitly quantify a city's industrial employment share of the high-tech activities. The UIS developed in this paper can be used in the evaluation of urban industrial composition and related industrial upgrading policies.

4.3.2 The Explanatory Variables and Estimation Functions

From Equation (29), we know that the employment share of high-tech industries of a city (represented by the UIS) is a nonlinear function of the city's agglomeration scale (L_j), firm market accesses of high-tech and low-tech industries ($\frac{FMA_{HTj}}{FMA_{LTj}}$), and the city's first natures provided for high-tech and low-tech industries ($\frac{R_{LTj}}{R_{HTj}}$). Our focus is on the effect of urban agglomeration. We begin to search the proxies for these factors.

First, we look for the proxy for urban agglomeration. Generally, there have been two measures for urban agglomeration: (a) total employment or population and (b) employment or population density (Melo et al., 2009). The initial and common

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[51] See Herrendorf et al. (2013) for a review.

[52] Just consider the tourist cities/countries, which have large shares in the service sector but have low intensities in technological activities.

approach was to use total population and employment (e.g., Aberg, 1973; Sveikauskas, 1975; Moomaw, 1981; Moomaw, 1983; Moomaw, 1985; Nakamura, 1985; Sveikauskas et al., 1988; Zheng, 2001) to represent the level of urban agglomeration. Ciccone and Hall (1996) and Zheng (2007) introduced the use of employment density and/or population density. Ciccone and Hall illustrated that density is a better measurement than the total number since it represents the intensity of labor and human capital relative to physical space. However, Combes and Gobillon (2015, p.24) noted that both of the measures are important.

Here, we use both of total employment (em) and employment density (ed) to represent Urban agglomeration. We expect the effects of them to be positive for the UIS since it increases with agglomeration economies, as shown in Equation (29).

Second, we use four indicators to control for the effects of firm market accesses (FMA_{HTi} and FMA_{LTi}). They are the city's port accessibility (pa), airport accessibility (aa), high-speed railway station (hr), and location in any metropolitan areas (kantome, kinkime, nagoyame, otherme). Concerning the first nature effects, the city's administrative property (whether is a designated city or not (dec)) will be used.

From the above discussion, we can define the following two basic estimation functions, in which except for dummy variables, all variables take the log value:

$$lnUIS = \alpha * lnem + \beta * lnpa + \gamma * lnaa + \delta * lnhr + \varepsilon * kantome + \epsilon * kinkime + \theta * nagoyame + \mu * otherme + \varphi * dec + \alpha_0 + \varepsilon_1 \tag{4.32}$$

$$lnUIS = a * lned + b * lnpa + c * lnaa + d * lnhr + e * kantome + f * kinkime + g * nagoyame + h * otherme + i * dec + a_0 + \varepsilon_2 \tag{4.33}$$

where the signs of α and a are expected to be positive. α_0 and a_0 are intercept terms, and ε_1 and ε_2 are error terms.

Furthermore, as Davis and Dingel (2014) modeled, intercity gaps of land prices and wages generate factor driven comparative advantage. To distinguish the effects of urban agglomeration from those of land price and wages, the city's average land price (lp) and annual incomes of taxpayers (in) will also be introduced in the extended versions of the above functions. We use two-period panel data (year 2006 and 2009) on 266 Japanese cities with total employment larger than 30,000 in the year 2006 (The cities having administrative area change during the period are excluded). The details of all the variables in (4.32) and (4.33) are given in the Appendix.

4.4 Estimated Results

Table 4.2 presents the estimated results concerning the regression functions (4.32) and (4.33) and their extended versions using Ordinary Least Squares (OLS).

Table 4.2 Estimated results of the urban industrial stage (UIS)

	(1)	(2)	(3)	(4)	(5)	(6)
Explanatory Variables	lnUIS	lnUIS	lnUIS	lnUIS	lnUIS	lnUIS
Intercept	-1.022***	-4.932***	-4.622***	-0.555***	-4.416***	-4.328***
	(-6.24)	(-11.06)	(-9.75)	(-4.46)	(-9.22)	(-9.88)
lnem	0.050***	0.023**	0.018*			
	(5.06)	(2.41)	(1.81)			
lned				0.041***	0.021***	0.017**
				(6.87)	(3.34)	(2.42)
lnin		0.596***	0.532***		0.553***	0.526***
		(9.29)	(7.37)		(8.31)	(7.29)
lnlp			0.024			0.014
			(1.91)			(0.99)
lnpa	0.015	0.000	-0.004	0.011	-0.001	-0.003
	(0.85)	(0.00)	(-0.24)	(0.65)	(-0.05)	(-0.18)
lnaa	0.015	-0.012	-0.008	0.008	-0.013	-0.010
	(0.83)	(-0.70)	(-0.46)	(0.49)	(-0.78)	(-0.62)
hr	-0.004	-0.002	-0.004	0.014	0.007	0.005
	(-0.21)	(-0.13)	(-0.21)	(0.78)	(0.39)	(0.27)
kantome	-0.014	-0.080***	-0.091***	-0.077***	-0.107***	-0.109***
	(-0.66)	(-3.81)	(-4.91)	(-3.38)	(-4.92)	(-5.00)
kinkime	-0.040*	-0.076***	-0.083***	-0.094***	-0.100***	-0.101***
	(-1.94)	(--3.87)	(-4.18)	(-4.41)	(-4.98)	(-5.00)
nagoyame	0.006	-0.055*	-0.050*	-0.040	-0.074**	-0.068**
	(0.19)	(-1.88)	(-1.69)	(-1.28)	(-2.51)	(-2.26)
otherme	-0.014	-0.037*	-0.036*	-0.041*	-0.048**	-0.046**
	(-0.63)	(-1.73)	(-1.70)	(-1.84)	(-2.30)	(-2.19)
dec	-0.029	-0.048	-0.051	0.001	-0.032	-0.034
	(-0.81)	(-1.45)	(-1,52)	(0.04)	(-1.08)	(-1.16)
Year 2006	0.049***	0.043***	0.043***	0.050***	0.044***	0.044***
	(4.39)	(4.10)	(4.17)	(4.56)	(4.21)	(4.22)
Number of	532	532	532	532	532	532
R^2	0.159	0.264	0.267	0.191	0.271	0.271

Notes: *t* values are in parentheses. ***, ** and * indicate significance at the levels of 1%, 5% and 10%, respectively. Except for the dummy variables, all variables use the log values.

Columns (1) and (4) correspond to the basic regression functions (4.32) and (4.33). In Columns (2) and (5), annual incomes of taxpayers are introduced. In Columns (3) and (6), land prices are further added. Columns (1), (2) and (3) focus on the effect of total employment (em), Columns (4), (5) and (6) represent the effect of employment density (ed).

All of the estimated results show the coefficients of urban agglomeration (i.e., lnem and lned) are significantly positive. Thus, the core proposition of this paper, that is, urban agglomeration (reflected by total employment or employment density) positively contributes to the urban industrial upgrading (reflected by the urban industrial stage index), is confirmed. In other words, a percentage of increase in total employment (employment density) increases the urban industrial stage index by 0.018 - 0.050% (0.017 - 0.041%), ceteris paribus.

Moreover, Columns (2), (3), (5) and (6) indicate the coefficients of annual incomes of taxpayers (i.e., lnin) are significantly positive, but average land price (i.e., lnlp) are not. In this sense, the theoretical model developed in this paper can be considered as a sound basis to study the effects of urban agglomeration on the industrial upgrading in Japan, which seems to be able to explain the mechanism of urban industrial upgrading better than the model of Davis and Dingel (2014), which focuses on the effects of land price and wage of labor.

Unfortunately, the coefficients of port accessibility (i.e., lnpa) and airport accessibility (i.e., lnaa) are not significant.

The coefficients of high-speed railway dummy (i.e., hr) are neither significant. This result is contrary to the common sense that the connection to high-speed railway stations stimulates knowledge spillover and innovation (Inoue et al, 2017). One explanation for this result could be that the connection to high-speed railway stations attracts rather low-tech service activities such as personal services and wholesale and retail trade than high-tech activities. But, this interpretation requires further analysis, which is beyond the scope of this paper.

The coefficients of all the metropolitan area dummies have negative signs in all of the regressions. Most coefficients of the two largest metropolitan area dummies (i.e., kantome and kinkime) are significant at the 1% level. That is, the cities located in larger metropolitan areas (especially Tokyo and Osaka) tend to have lower urban industrial stage indexes, ceteris paribus. Two explanations could be considered. (a) A periphery city's closer connection to a metropolis may lead to the movement of skilled-labor and high-tech activities from it to the metropolis because they could benefit more from urban agglomerated economies. Faber (2014) and Qin (2017) showed that the improvement of transportation led to a reduction in GDP growth in peripheral counties in China. (b) A better transportation network between metropolis and peripheral counties would cause the relocation of the low-tech but land-intensive activities from the metropolis to peripheral counties. Baum-Snow et al (2017) found that the construction of transportation facilities decentralizes service and manufacturing activities away from the central city to suburban regions.

4.5 Conclusion

This paper presented a two-industry model of urban system to show that urban agglomeration (reflected by total employment or employment density) contributes to the industrial upgrading, because high-tech industries benefit more from agglomeration economies. To verify this theoretical conclusion, we developed an industrial stage index using the industry's employment share of engineers, administrative and managerial workers, input coefficient of education and scientific research, and input coefficient of information and communication. Based on it, we defined an urban industrial stage index (UIS) by adding up the product of an industry's employment share of a city and its industrial stage index, to reflect the city's intensity in high-tech activities. Regression functions based on the theoretical conclusion were estimated via OLS using city-level data from Japan's economic census. The estimated results showed that a percentage of increase in total employment (employment density) increases the urban industrial stage index by 0.018% - 0.050% (0.017% – 0.041%), ceteris paribus.

The present paper indicated the importance of urban employment agglomeration in the industrial upgrading process. This implies that to keep the industrial upgrading in cities, it is needed to allow population agglomerate in larger cities and to centralize population.

Moreover, the findings of this paper could be applied to explaining the failure of Japan's 'technopolis' project[53]. As Ozawa (2005, p. 99) noted:

> "The technopolises were soon found to be incapable of attaining the critical mass needed to generate the *agglomeration effect*."

The reason of the failure, i.e., the lack of agglomeration economies, was also accentuated by Tatsuno (1990, p. 97) using the following words:

> "Another setback was that regional governments initially focused their effects on 'hard' infrastructure projects, such as roads, airports, and highways, and

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[53] The technopolis project was initiated in 1984 under the Technopolis Law of 1983. It was designed to set up twenty 'technopolises' across Japan's archipelago corridor. Each technopolis is an integrated complex of high-tech industries, research universities, local supporting industries, housing, and communications and transportation facilities, a high-tech cluster that engenders economies of linkage and agglomeration.

> underestimated the difficulty of developing the ‘soft’ infrastructure of R&D consortia, venture capital funds, and university research needed to drive the engineers who still prefer to live and work in the Tokyo area, whose wealth of educational and culture resources attracts 80 percent of the nation’s researchers. Unlike Tokyo or Silicon Valley, the technopolises are not beneficiaries of a natural flow of people and jobs.”

Similarly, the failure of the “regional research core” program[54] is another example. In fact, the main aim of these projects and programs was to disperse industrial concentration away from overcrowded Tokyo, promoting better allocation of industrial activities throughout the country for both environmental and economic efficiency reasons. However, due to the failure of considering the agglomeration economies, dispersion of economic activity may have impeded the industrial upgrading in Japan. These are the policy implications based on the theoretical and empirical results of this paper.

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[54] The regional research core project was introduced by MITI (Ministry of International Trade and Industry) in 1986. Twenty-eight core clusters were set up at the end of 1980s. However, they failed to create the intended viable research clusters, since business services and amenities are not available in those isolated rural locations chosen by the MITI’s regional research core project (Ozawa, 2005, pp. 99-101).

4.A Appendix

Table 4.A The definitions of variables and sources of data

UIS	The urban industrial stage of a city, defined in Equation (31)	*Japan Economic Census for Business Frame, years 2006,2009*
em	Total employment (employed in privately owned establishments) in a city	*Japan Economic Census for Business Frame, years 2006,2009*
ed	Total employment per total administrative area	*Japan Economic Census for Business Frame, years 2006,2009*
in	The annual incomes of taxpayers	*Investigation of Taxation of Municipality, years 2006, 2009*
lp	Average land price of all kinds of usage in a city	*Average price and average change to previous year of use-specific land of municipalities and prefecture, years 2006, 2009*
aa	The summation of the passengers of the five international airports divided by the distances between them and the city hall of the city in question. See Equation (A.6)	*Investigation of Airport, years 2006, 2009*
pa	The summation of the trade values of the five international ports divided by the distances between them and the city hall of the city in question. See Equation (A.8).	*Port Statistics, years 2006, 2009*
hr	Be 1 if the city in question has at least one Shinkansen station within its administrative area in year 2006 and 2009, or be 0 otherwise	*Wikipedia pages of on 266 observation cities,* *Wikipedia pages of shinkansen, the history graph of shinkansen, year 2017*

dec	Be 1 if the city in question is a designated city in year 2017, or be 0 otherwise	*Wikipedia page on Cities designated by government ordinance for Japan, year 2017*
kantome	Be 1 if the city in question (except designated cities) is in Kanto metropolitan area in year 2013, or be 0 otherwise	*Names of Shi ,Machi and Mura of Major Metropolitan Areas, year 2013*
kinkime	Be 1 if the city in question (except designated cities) is in Kinki metropolitan area in year 2013, or be 0 otherwise	*Names of Shi ,Machi and Mura of Major Metropolitan Areas, year 2013*
chukyome	Be 1 if the city in question (except designated cities) is in Chukyo metropolitan area in year 2013, or be 0 otherwise	*Names of Shi ,Machi and Mura of Major Metropolitan Areas, year 2013*
otherme	Be 1 if the city in question (except designated cities) is in the other metropolitan areas (except Kanto, Kinki, Chukyo) in year 2013, or be 0 otherwise	*Names of Shi ,Machi and Mura of Major Metropolitan Areas, year 2013*

$$aa_i = \sum_{a=1}^{5} \frac{total\ passengers\ in\ 2015_a}{distance\ _{ia}} \tag{4A.6}$$

where $total\ passengers\ in\ 2015_a$ is the total passengers (person) of one of the five international airports (Narita International Airport, Tokyo International Airport, Chubu International Airport, Osaka International Airport, Kansai International Airport) in year 2015. $distance\ _{ia}$ is the distance between the city hall of city *i* and international airport *a,* which is calculated by the following spherical law of cosines:

$$distance_{ia} = 6371 \times \arccos[\sin lat_i \times \sin lat_a + \cos lat_i \times \cos lat_a \times \sin(lon_i - lon_a)] \qquad (4A.7)$$

where 6371 is the mean earth radius (6371km), lat_i is latitude in radians of the city hall of city i, lon_i is longitude in radians of it. lat_a is latitude in radians of airport a and lon_a is the longitude in radians of it. The data are collected from the Wikipedia pages on the 266 cities and the five international airports.

$$pa_i = \sum_{p=1}^{5} \frac{total\ trade\ value\ in\ 2015_p}{distance_{ip}} \qquad (4A.8)$$

where $total\ trade\ value\ in\ 2015_p$ is the total trade value (billion yen) of Port p of the five major ports (Port of Tokyo, Port of Yokohama, Port of Nagoya, Port of Osaka, Port of Kobe) in year 2015, and $distance_{ip}$ is the distance between the city hall of city i and Port p, which is calculated similarly using Equation (4A.7).

Chapter 5

Conclusions

5.1 Main Results of this Dissertation

This dissertation investigated the industrialization process with production differentiation, and applied the models of regional and urban economies to analyze the formation of regional industrial structure and the causes of urban industrial upgrading.

In the dissertation, Chapter 2 introduced the production differentiation (using the Dixit-Stiglitz (1977) monopolistic competition framework) into the basic MSV model, which showed that an industrializing firm contributes to the demand for other firms' products *only* by distributing its profits and raising aggregate income. The chapter showed that, with high product substitutability, industrializing sectors will reduce their prices and steal sales from their competitors, leading to a business-stealing effect. Moreover, it also indicated that if this business-stealing effect dominates the aggregate demand spillovers, the profits of industrializing monopolists will decline with the industrialization level, and the industrialization process will not be necessarily self-sustaining, which suggests two additional neglected industrialization patterns, partial industrialization and ruinous competition, which have been neglected in the existing literature.

Chapter 3 shifted the view from national industrialization to regional industrial structures. It extended Krugman's original model to a two-industry and two-factor case where the manufacturing activities are classified into intermediate input-intensive (high-tech) industries and labour-intensive (low-tech) industries, as done in Matsuyama (1996). In particular, it used local fixed capital stocks to represent the local variety of intermediate input, hence, it connects the local variety of intermediate inputs with the local productivity and enables the endogenous analysis of regional productivity. Then, it showed that the region with more fixed capital stocks has an absolute advantage in both the two manufacturing industries and has a comparative advantage in the capital-intensified high-tech industry. These advantages lead to such regional manufacturing structures that the capital-abundant region has larger revenues of the two manufacturing industries (reflecting the absolute advantage) and has larger revenue ratio of the high-tech to low-tech industries (reflecting the comparative advantage). These theoretical inferences were supported using some evidence from the data on the regional industrial structures in China.

Chapter 4 extended Henderson's model (1974) of urban system into a two-industry case where there is inter-urban trade and industry-specific agglomeration economies. It theoretically showed that cities with larger total employment or higher employment density will have comparative advantages and specialize in the production of high-tech goods. It also developed an industrial stage index to reflect industries' input intensities in high-tech activities (skilled labour, scientific research and education, and information and communications) and then used this index with cities' industrial employment composition to build an urban industrial stage index for cities, which reflects cities' intensities in high-tech activities. The relationship between urban agglomeration (reflected by total employment or employment density) and industrial upgrading (reflected by the urban industrial stage index) was verified by using city-level panel data collected from Japan's economic census.

5.2 Contributions and Policy Implications

This dissertation clarified the role of product differentiation in the industrialization process, analyzed the formation of industrial structures in regional economies, and the relationship between agglomeration and industrial upgrading in urban economies.

Chapter 2 found that with high product substitutability, industrializing sectors will reduce their prices and steal the sales from their competitors, leading to a business-stealing effect. If this business-stealing effect dominates the aggregate demand spillovers, the profits of industrializing monopolists will decline with the industrialization level, and the industrialization process will not be necessarily self-sustaining, which suggests two additional industrialization patterns, partial industrialization and ruinous competition. To focus on the effects of aggregate demand on industrialization, MSV neglected production differentiation because it assumed unit-elastic demand, which means that industrialized firms always refrain from price-cutting. The findings of the business-stealing effect and the existence of partial industrialization and ruinous competition in the industrialization process can be considered as a contribution to the existing literature.

Chapter 3 illustrated the following three results. (i) The region with more fixed capital stocks has an absolute advantage in both the high-tech and low-tech industries. It also has a comparative advantage in the high-tech industry, which uses the fixed capital more intensively. In contrast, the region with less fixed capital stocks has no absolute advantage, but it has a comparative advantage in the labour-intensified (low-tech) industry. (ii) The capital-abundant region has a manufacturing structure dominated by relatively more high-tech industries than that of the region with less fixed capital stocks.

With the exception that the fixed capital stock gap between the two regions is beyond a certain value, a larger gap of fixed capital stock usually leads to a larger gap in regional manufacturing structures. (iii) The majority of labor will be located in the capital-abundant region, and the amount of labor in this region will increase as the local fixed capital stocks increase.

Recall that Krugman's new economic geography (NEG) model (1991) made a symmetric assumption on the production of variety goods, and the majority of NEG studies aggregated the production activities (excluding agriculture) into one kind of the variety goods, failing to model the characteristics of different manufacturing activities. These studies always assumed an exogenous interregional productivity gap, which determines regional comparative advantage and industrial structures, without explaining how the productivity gap was formed. Because the formation of regional comparative advantage and the role of local fixed capital stock in the formation of regional manufacturing structures have been modelled and investigated in this dissertation, it can be considered as a contribution to the NEG literature.

Chapter 4 introduced industry-specific agglomeration economies into the classical model of urban system (Henderson, 1974) by assuming that high-tech industries benefit more from agglomeration economies. It showed that urban agglomerations will gain comparative advantage and relatively specialize in high-tech industries.

It also developed an industrial stage index, which reflects industries' input intensities in high-tech activities (skilled labour, scientific research and education, and information and communications), and then used this industrial stage index and cities' industrial employment composition to build an urban industrial stage index for cities, which reflects their employment intensities in high-tech activities. The association between urban agglomeration (reflected by total employment or employment density) and industrial upgrading (reflected by urban industrial stage index) was verified using city-level panel data of the Japanese economic census.

The mainstream of urban economies has not paid enough attention to industrial upgrading analysis. The focus of urban system models (Henderson, 1974) seems to be ill-suited to explain the mechanism of urban industrial upgrading since it generally assumed that a firm enjoys positive externalities from only the intra-industry spatial concentration of economic activities. In this sense, the introduction of industrial-specific agglomeration economies and the findings of the relationship between urban agglomeration and industrial upgrading in this dissertation can be considered as a contribution to urban economic studies.

The previous literature on industrial upgrading (Ozawa, 2005; Baumol, 2002) illustrated the industrial upgrading stage descriptively. To the best of the dissertation author's knowledge, this dissertation made the first attempt to explicitly quantify cities' intensities in high-tech activities. The UIS developed here can be considered as a contribution to the industrial upgrading literature.

The above mentioned contributions also have following important policy implications. (a) To stimulate the industrialization of agriculture in China, local governments need to help farmers to increase the product differentiation of agriculture. They can help farmers to build their local brands to make their products more diverse. Farmers can also help each other by forming the agriculture cooperatives to realize unified sales and gain monopolistic power (like the wave of mergers after a wave of investment in the manufacturing during the boom of the late 1880s and early 1890s in America). (b) To improve the industrial structure of the interior region of a country like

China and realize more balanced economic growth between coastal and interior regions, the government needs to enhance the fixed capital investment in the interior region. For example, the government can invest more in the development of infrastructure in the interior region. (c) To stimulate the industrial upgrading in cities and recover the economy of a country like Japan, the government needs to encourage people to agglomerate in large cities and centralize its population. Meanwhile, in the location chosen to implement industrial upgrading policies, such as Japan's 'technopolis' project, cities with larger total employments or higher population density should be considered with higher priority.

5.3 Research Subjects for the Future

This final section indicates the insights that have been illustrated in the previous three chapters and suggests some directions for the future research.

5.3.1 Future Research Regarding Chapter 2

Product differentiation and the big push. Chapter 2 has indicated the basic MSV industrialization model where profits are the only channel of positive demand spillovers. As a result, the industrialization equilibrium cannot coexist with the unindustrialized one in which unprofitable investments will reduce income and then the size of other firms' markets. So, the model developed in Chapter 2 cannot be used to investigate the conditions of the big push. Furthermore, MSV also presented three extended models to show the conditions of the big push. Specifically, they mentioned three types of external economies generated from industrialization, which means that a firm's profit is not an adequate measure of its contribution to the profits of manufacturers. For these reasons, the equilibriums of industrialization and unindustrialization could coexist (See the cases (i), (ii) and (iii) in Chapter 2, pp. 14-15).

The industrialization model with product differentiation developed in Chapter 2 can be used to investigate the role of product differentiation in the existence of the big push. It can be expected that the condition of the existence of the big push will become more stringent when product differentiation is considered. That is, when the product differentiation goes beyond a certain range can the big push occur.

Social welfare analysis. Although Chapter 2 revealed the role of production differentiation in the industrialization process, its effects on social welfare remain unclear. Shleifer and Vishny (1988, pp. 1225) mentioned that once production differentiation is considered in the industrialization process, social welfare analysis would become very complex. They wrote (p. 1225):

> "The situation becomes more complex when demand is elastic, and the cost-reducing firm raises consumer surplus and so may raise welfare even when its investment does not break even. However, it also steals sales and profits from cost-reducing firms in other sectors to recoup its fixed cost and thus may reduce welfare even when its own investment is profitable. The interplay of these two opposing effects can lead to either too little or too much investment by potential cost-reducing firms."

That is, on the one hand, cost-reducing firms lower the market price and raise the consumer surplus; on the other hand, they steal sales and profits from other sectors, which can lead to excessively minimal investment. This issue needs to be examined in the future.

5.3.2 Future Research Regarding Chapter 3

Transportation Costs and Regional Manufacturing Structures. For simplicity, Chapter 3 neglected the analysis of transportation costs. However, through the comparison of the free trade case and the non-trade case, one can image that the local revenue share of high-tech industry in the capital-abundant region and that of low-tech industry in the region with less capital are both larger in the free-trade economy than the no-trade one. This implies that the decrease of transportation costs may enlarge the industrial structure gap between the capital-abundant region and the region with less capital. To explicitly examine the effects of free interregional trade on *regional manufacturing structures*, one needs to introduce transportation costs into the model developed in Chapter 3, which is left for the future.

5.3.3 Future Research Regarding Chapter 4

Urban industrial upgrading and the rise or full of cities. Although Chapter 4 verified the effects of employment agglomeration on urban industrial upgrading, the inverse relation, that is, the effects of urban industrial upgrading on the total employment or employment density of cities, remains to be accounted for. Moretti (2012) illustrated that the rise or fall of a city lies in whether it can upgrade its industrial structure. This kind of setting can be used to study the effects of urban industrial upgrading on agglomeration or dispersion of population, which will be attempted in the future.

References

Abdel-Rahman, H. M. and Anas, A. (2004). Theories of Systems of Cities, *Handbook of Regional and Urban Economics*, Vol.5, Ch. 4: 171-245.

Aberg, Y. (1973). Regional Productivity Differences in Swedish Manufacturing. *Regional and Urban Economics*, 3:131–155.

Abdel-Rahman, H. M. and Fujita, M. (1993). Specialization and Diversification in a System of Cities. *Journal of Urban Economics*, 33: 258–276.

Abdel-Rahman, H. M. (1996). Why Do Cities Specialize in Production? *Regional Science and Urban Economics*, 26: 1-22.

Aghion, P. and Howitt, P. (1990). A Model of Growth Through Creative Destruction. *NBER WORKING PAPER SERIES,* w3223.

Amiti, M. (1998). New Trade Theories and Industrial Location in the EU: A Survey of Evidence. *Oxford Review of Economic Policy*, 14: 45–53.

—— (2005). Location of Vertically Linked Industries: Agglomeration Versus Comparative Advantage. *European Economic Review*, 49: 809–832.

Anas, A. and Xiong, K. (2003). Intercity Trade and the Industrial Diversification of Cities. *Journal of Urban Economics*, 54: 258–276.

Andini, M., Blasio, G., Duranton, G. and Strange, W. C. (2013). Marshallian Labour Market Pooling: Evidence from Italy. *Regional Science and Urban Economics*, 43: 1008-1022.

Armington, P. S. (1969). The Geographic Pattern of Trade and the Effects of Price Changes. *IMF Staff Papers,* 17: 488–523.

Baumol, W. J. (2002) *The Free-Market Innovation Machine; Analyzing the Growth*

Miracle of Capitalism. New Jersey: Princeton University Press.

Baum-Snow, N. and Pavan, R. (2013). Inequality and City Size. *Review of Economics and Statistics*, 95: 1535-1548.

Behrens, K. and Robert-Nicoud, F. (2015). Agglomeration Theory with Heterogeneous Agents. *Handbook in Regional and Urban Economics*, Vol.5, Ch. 4: 171-245.

Blanchard, O. J. and Kiyotaki, N. (1987). Monopolistic Competition and the Effects of Aggregate Demand. *The American Economic Review*, 77: 647-666.

Brander, J. A. and Spencer, B. J. (2015). Intra-industry Trade with Bertrand and Cournot Oligopoly: The Role of Endogenous Horizontal Product Differentiation. *Research in Economics,* 69: 157-165.

Broda, C. and David, E. W. (2006). Globalization and the Gains from Variety. *Quarterly Journal of Economics,* 121: 541–585.

Carlino, G. and Kerr, W. R. (2015) Agglomeration and Innovation. *Handbook of Regional and Urban Economics*, Vol.5, Ch. 6: 349-404.

Chipman, J. S. (1970). External Economies of Scale and Competitive Equilibrium. *Quarterly Journal of Economics*, 84: 347-385.

Cleveland, W. S. (1979). Robust Locally Weighted Regression and Smoothing Scatterplots. *Journal of the American Statistical Association*, 74: 829-836.

Collie, D. R. (2016). Gains from Variety? Product Differentiation and the Possibility of Losses from Trade under Cournot Oligopoly with Free Entry. *Economics Letters,* 146: 55-58.

Combes, P. and Gobillon. L. (2015). The Empirics of Agglomeration Economies. *Handbook of Regional and Urban Economics*, Vol. 5, Ch. 5: 247-348.

Davis D. R. and Dingel, J. I. (2014). The Comparative Advantage of Cities. *NBER*

WORKING PAPER SERIES, No. w20602.

Deane, P. (1979). *The First Industrial Revolution*. Cambridge: Cambridge University Press.

DeLong, J., Bradford, D. J. and Summers, L. H. (1991). Equipment Investment and Economic Growth. *Quarterly Journal of Economics*, 106: 445-502.

Dixit, A. and Stigliz, J. (1977). Monopolistic Competition and Optimum Product Diversity. *The American Economic Review*, 76: 297–308.

Di Addario, S. (2011). Job Search in Thick Markets. *Journal of Urban Economics*, 69: 303-318.

Duranton, G. and Puga, D. (2000). Diversity and Specialization in Cities: Why, Where and When Does it Matter? *Urban Studies*, 37: 533-555.

—— (2001). Nursery Cities: Urban Diversity, Process Innovation, and the Life Cycle of Products. *The American economic Review*, 91: 1454-1477.

—— (2004). Micro-foundations of Urban Agglomeration Economies. *Handbook of Regional and Urban Economics*, Vol. 4, Ch. 48: 2063-2117.

—— (2004). From Sectoral to Functional Urban Specialization. *Journal of Urban Economics*, 57: 343-370.

Ehrl, P. (2013) Agglomeration Economies with Consistent Productivity Estimates. *Regional Science and Urban Economics*, 43: 751–763.

Ellison, G., Glaeser, E. L. and Kerr, W. R. (2010). What Causes Industry Agglomeration? Evidence from Coagglomeration Patterns. *The American Economic Review*, 100: 1195-1213.

Ethier, W. (1979). Internationally Decreasing Costs and World Trade. *Journal of International Economic*s, 9: 1–24.

—— (1982). National and International Returns to Scale in the Modern Theory of International Trade. *The American Economic Review*, 7: 389–405.

Faber, B. (2014). Trade Integration, Market Size, and Industrialization: Evidence from China's National Trunk Highway System. *Review of Economic Studies*, 81: 1046-1070.

Feldman, M. (2008). Job Hopping, Earnings Dynamics, and Industrial Agglomeration in the Software Publishing Industry. *Journal of Urban Economics*, 64: 590-600.

Fukao, K, Miyagawa, T, Pyo, H and Rhee, K. (2009) Estimates of Multifactor Productivity, ICT Contributions and Resource Reallocation Effects in Japan and Korea. *RIETI Discussion Paper Series*, No. 09-E-021.

Fujita, M. (1988). Monopolistic Competition Model of Spatial Agglomeration: Differential Product Approach. *Regional Science and Urban Economics*, 18: 87-124.

Fujita, M., Krugman, P. and Venables, A. J. (1999). *The Spatial Economy: Cities, Regions, and International Trade*, MIT: The MIT Press.

Fujita, M., Mori, T., Henderson, J. V. and Kanemoto, Y. (2004). Spatial Distribution of Economic Activities in Japan and China. *Handbook of Regional and Urban Economics*, Vol.4, Ch. 65, 2911–2977.

Fujita, M. and Hu, D. (2001). Regional Disparity in China 1985–1994: The Effects of Globalization and Economic Liberalization. *Annals of Regional Science*, 35: 3–37.

Fujita, M. and Thisse, J.-F. (2013). Does Geographical Agglomeration Foster Economic Growth? And Who Gains and Loses from It? *The Japanese Economic Review*, 54: 121-145.

—— (2013). *Economics of Agglomeration, Cities, Manufacturing Location, and Globalization*. Cambridge: Cambridge University Press.

Forslid, R. and Wooton, I. (2003). Comparative Advantage and the Location of Production. *Review of International Economics,* 11: 588–603.

Gao, F. (2015). International Experience to Improve Agricultural Productivity and China's Choice. *Fudan Journal (Social Sciences)*, No.1, 116-124. (in Chinese)

Gossen, H. H. (1984). *Entwickelung der Gesetze des Menschlichen Verkehrs, Braunschweig: Vieweg und Sohn*. Translated by Rudolph C. Bliss as "The Laws of Human Relations and the Rules of Human Action Derived Therefrom," MIT, The MIT Press.

Han, S., Xiang, G. C. and Wang, J. C. (2007). Agricultural Diversity and Efficiency Improvement of Peasant's Economy: Theory Analysis, Empirical Proof and International Comparison. *The Journal of Quantitative & Technical Economics,* No.1, 2007, 56-64. (in Chinese)

Head, K. and Mayer, T. (2004). The Empirics of Agglomeration and Trade. *Handbook of Regional and Urban Economics*, Vol. 4, Ch. 59: 2609–2669.

Henderson, J. V. (1974). The Sizes and Types of Cities. *The American Economic Review*, 64: 640-656.

—— (1997). Medium Size Cities. *Regional Science and Urban Economics,* 27: 583-612.

—— (2003). Marshall's Scale Economies. *Journal of Urban Economics*, 53: 1–28.

Henderson, J. V., Kuncoro, A. and Turner, M. (1995). Industrial Development in Cities. *Journal of Political Economy*, 103: 1067-1090.

Herrendorf, B., Rogerson, R. and Valentinyi, Á. (2013). Growth and Structural Transformation. *NBER WORKING PAPER SERIES*, No. w18996.

Hendrics, L. (2011). The Skill Composition of U.S. Cities. *International Economic Review*, 52: 1-32.

Hu, D. (2002). Trade, Rural-urban Migration, and Regional Income Disparity in Developing Countries: A Spatial General Equilibrium Model Inspired by the Case of China. *Regional Science and Urban Economics*, 32: 311–338.

Inoue, H., Nakajima, N., and Umeno, S. (2017). The Impact of the Opening of High-Speed Rail on Innovation. *RIETI Discussion Paper Series*, 17-E-034.

Jones, E. (1920). Is Competition in Industry Ruinous? *Quarterly Journal of Economics,* 34: 473-519.

Knauth, O. W. (1916). Capital and Monopoly. *Political Science Quarterly*, 31: 244-259.

Krugman, P. (1991). Increasing Returns and Economic Geography, *Journal of Political Economy*, 99: 483-499.

Knight, E. and Wójcik, D. (2017). Geographical Linkages in the Financial Services Industry: a Dialogue with Organizational Studies. *Regional Studies*, 51: 1-12.

Lamoreaux, N. R. (1980). Industrial Organization and Market Behavior: The Great Merger Movement in American Industry. *Journal of Economic History*, 40: 169-171.

Lin, Y. (2011). New Structural Economics: A Framework for Rethinking Development. *The World Bank Research Observer,* 26: 193–221.

Mankiw, N. G. and Whinston, M. D. (1986). Free Entry and Social Inefficiency. *RAND Journal of Economics,* 17: 48-58.

Martin, P. and Rogers, C. (1995). Industrial Location and Public Infrastructure.

Journal of International Economics, 39: 335-351.

Martin, R. and Sunley, P. (2003). Deconstructing Clusters: Chaotic Concept or Policy Panacea. *Journal of Economic Geography*, 3: 5-35.

Martin, R. and Sunley, P. (2011). Conceptualizing Cluster Evolution: Beyond the Life Cycle Model? *Regional Studies*, 45: 1299-1318.

Matsuyama, K. (1991). Increasing Returns, Industrialization, and Indeterminacy of Equilibrium. *Quarterly Journal of Economics,* 106: 617-650.

—— (1992). The Market Size, Entrepreneurship, and the Big Push. *Journal of the Japanese and International Economies,* 6: 347-364.

—— (1996). Why are There Rich and Poor Countries? Symmetry-breaking in the World Economy. *Journal of the Japanese and International Economies*, 10: 419–439.

Melo, P. C., Graham, D. J. and Noland, R. B. (2009). A Meta-analysis of Estimates of Urban Agglomeration Economies. *Regional Science and Urban Economics*, 39: 332–342.

Moomaw, R. L., (1981). Productivity and City Size: A Critique of the Evidence. *Quarterly Journal of Economics,* 96: 675-688.

—— (1983). Is Population Scale a Worthless Surrogate for Business Agglomeration Economies? *Regional Science and Urban Economics*, 13: 525–545.

—— (1985). Firm Location and City Size: Reduced Productivity Advantages as A Factor in the Decline of Manufacturing in Urban Areas. *Journal of Urban Economics*, 17: 73–89.

Morreti, E. (2013). *The New Geography of Jobs*. London: Mariner Books Presssed.

Murphy, K. M., Shleifer, A. and Vishny, R. W. (1989). Industrialization and the Big Push. *Journal of Political Economy,* 97: 1003-1026.

Nakamura, R. (1985). Agglomeration Economies in Urban Manufacturing Industries: A Case for Japanese Cities. *Journal of Urban Economics*, 17: 108–124.

Ohlin, B. (1933). *Interregional and International Trade,* Harvard University Press.

Overman, H. G., Redding, S. and Venables, A. (2003). The Economic Geography of Trade, Production, and Income: A Survey of Empirics. *Handbook of International Trade*, Ch. 12: 353–387.

Ozawa, T. (2005). *Institutions, Industrial Upgrading, and Economic Performance in Japan*. Massachusetts: Edward Elgar Press.

Picard, P. and Zeng, D.-Z. (2010). A Harmonization of First and Second Natures. *Journal of Regional Science*, 50: 973–994.

Porter, M. E. (1990). *Competitive Strategy: Techniques for Analyzing Industries and Competition.* New York: Free Press.

—— (1990). *The Competitive Advantage of Nations*. New York: Free Press.

—— (1998). Clusters and the New Economics of Competition. *Harvard Business Review*, November-December: 77-90.

Qin, Y. (2017). No County Left Behind? The Distributional Impact of High-speed Rail Upgrades in China. *Journal of Economic Geography*, 17: 489–520.

Redding, S. J. and Sturm, D. M. (2008). The Costs of Remoteness: Evidence from German Division and Reunification. *The American Economic Review*, 98: 1766-1797.

Ricardo, D. (1817). *Principles of Political Economy and Taxation.* London: John Murray Press.

Richard, R. N. (1956). A Theory of the Low-Level Equilibrium Trap in Underdeveloped Economies. *The American Economic Review,* 46: 894-908.

Ricci, L. (1999). Economic Geography and Comparative Advantage: Agglomeration versus Specialization. *European Economic Review*, 43: 357–377.

Rivera-Batiz, F. L. (1988). Increasing Returns, Monopolistic Competition, and Agglomeration Economies in Consumption and Production. *Regional Science and Urban Economics*, 18: 125–153.

Robinson, J. (1933). *The Economics of Imperfect Competition*. London: Macmillan pressed.

Romer, P. M. (1987). Growth Based on Increasing Returns Due to Specialization. *The American Economic Review*, 77: 56–62.

——(1990). Endogenous Technological Change. *Journal of Political Economy,* 98: 71–102.

Rosenthal, S. and Strange, W. C. (2003). Geography, Industrial Organization, and Agglomeration. *The Review of Economics and Statistics*, 85: 377-393.

—— (2004). Evidence on the Nature and Sources of Agglomeration Economies. *Handbook of Regional and Urban Economics*, Vol. 4, Ch. 49: 2119-2171.

Rosenstein-Rodan, P. (1943). Problems of Industrialization of Eastern and South-Eastern Europe. *Economic Journal*, 53: 202–211.

Sachs, J. D. and Warner, A. M. (1995). Natural Resource Abundance and Economic Growth. *NBER Working Paper,* No. w5398.

Schotter, A. P., Mudambi, R., Doz, Y. L. and Gaur, A. (2017). Boundary Spanning in Global Organizations. *Journal of Management Studies*, 54: 403-421.

Schumpeter, J. A. (1939). *Business Cycles: A Theoretical, Historical, and Statistical Analysis of the Capitalist Process*. New York: McGraw-Hill Book Company.

—— (1942). *Capitalism, Socialism and Democracy.* New York: Harper& Row Press.

Shleifer, A. (1986). Implementation Cycles. *Journal of Political Economy,* 94: 1163-1190.

Shleifer, A. and Vishny, R. W. (1988). The Efficiency of Investment in the Presence of Aggregate Demand Spillovers. *Journal of Political Economy,* 96: 1221-1231.

Sveikauskas, L. (1975). The Productivity of Cities. *Quarterly Journal of Economics,* 89: 393-413.

Sveikauskas, L., Gowdy, J. and Funk, M. (1988). Urban Productivity: City Size or Industry Size? *Journal of Regional Science*, 28: 185–202.

Tan, L. and Zeng, D.-Z. (2014). Spatial Inequality Between Developed and Developing Economies. *Papers in Regional Science*, 93: 229–248.

Tatsuno, S. M. (1990). *Created in Japan: From Imitators to World-Class Innovators.* New York: Ballinger Press.

Venables, A. (1996). Equilibrium Locations of Vertically Linked Industries. *Journal of International Economics*, 37: 314-359.

—— (1999). The International Division of Industries: Clustering and Comparative Advantage in a Multi-industry Model. *Scandinavian Journal of Economics,* 101: 495–513.

Wang, X.-P. (2007). An analysis of the Characteristics and Route of the Growth Rate of Agricultural Productivity in China. *The Journal of Quantitative & Technical Economics*, No. 1, 14-25. (in Chinese)

Whitehouse, E. (1995). Measures of Inequality in Stata. *Stata Technical Bulletin*, 23: 20–23.

Wheeler, C. (2001). Search, Sorting, and Urban Agglomeration. *Journal of Labor Economics,* 19: 879-899.

Wójcik, D., Knight, E. and Pažitka, V. (2018). What Turns Cities into International Financial Centres? Analysis of Cross-border Investment Banking 2000–2014. *Journal of Economic Geography*, 18: 1–33.

Zhang, J., Wu, G. and Zhang, J. (2007). Compilation of China's Provincial Capital Stock Series Using the Perpetual Inventory Method. *Paper presented to the International Workshop on Productivity in China.*

Zheng, X.-P. (2001). Determinants of Agglomeration Economies and Diseconomies: Empirical Evidence from Tokyo. *Socio-Economic Planning Sciences*, 35: 131–144.

Zheng, X.-P. (2007). Economies of Network, Urban Agglomeration, and Regional Development: A Theoretical Model and Empirical Evidence. *Regional Studies,* 41: 559–569.