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Abstract

This chapter provides a survey of recent developments of positive as well as normative theories of city systems. Static theory of city system emphasizes the factors that result in the formation of cities through the interaction between two opposing forces: i) agglomeration economy; ii) agglomeration diseconomy. Furthermore, the theory examines the interaction between cities within the national economy through intercity trade and migration, which shape the internal population composition and industrial structure of cities within the system. New development of this theory has been influenced by industrial organization and economic growth together with the new urban economic paradigm. This chapter focuses on the following questions: What are the factors that lead to the formation of cities? When do cities specialize in production and when do they diversify? When do both specialized cities and diversified cities coexist? What determines the number and sizes of cities of different types in an economy? What are the factors that determine skill distribution and income disparities among different types of cities? What are the impacts of income inequalities on welfare? What are the tax and or subsidy scheme that would result in a Pareto-efficient allocation of resources in a system of cities? Do we need the intervention of federal government in order to achieve a Pareto-efficient allocation of resources in a system of cities? These questions are addressed in a spatial general equilibrium model of a closed economy consisting of a system of monocentric cities.

Keywords: System of city size, trade, industrial structure.

JEL classification: H41, R12, R13.

1. Introduction

Why do population and economic activities concentrate in urban areas rather than disperse in space? Whey does most urban systems tends to be dominated by a large metropolitan area such as London, Praise, Tokyo, and New York, which have a diversified industrial composition and a divers labor force? Whey does the size of diversified cities tends to be larger than specialized ones? Whey does inter and intra city income disparities seem to be growing and that growth is more pronounced in developing countries? These are some questions that attracted the attentions of urban economist, regional scientists and economic geographers.

Addressing these question are becoming more important over time for four main reasons: (1) the growing percentage of population living in urban areas documented by the United Nations Report, which indicated that the world urban population increased from 30% in (1950) to 45% in (1995) and is expected to be 50% in (2005). Furthermore, the percentage of increase is larger in industrialized countries where it increased from 61% in (1960) to 73% in (1993). On the other hand, the number of the largest cities in the world (cities with population over 10 million) increased from only two cities in (1950) to fifteen cities in (1995) and is expected to grow to 26 in 2025 (United Nation1994); (2) most of the non-agriculture GDP in industrialized countries is produced in urban areas; (3) labor productivities and industrial growth are positively related to the local size of the industry as well as to the industrial composition in the city in which the industry locates.[1] Also it has been documented that some industries grow faster in cities with diversified industrial structure while other industries grow faster in specialized cities;[2] (4) trade liberalization and globalization, characterized by the emergence and the expansion of the

[1] See Rosenthal and Strange (2003) for a comprehensive survey of this literature.

European Union and with NAFTA, GATT, and some trade agreement between some European countries and some developing countries in North Africa. As a result of all this the role national government in influencing trade has been declining and the role of a city in a network of urban system is becoming more important. Thus, it is the comparative advantage of a city not national trade policy is what will shape the future of trade pattern. All of the above would lead us to conclude that a comprehensive theory of system of cities is not only an interesting theoretical exercise but an essential part in understanding economic growth and international trade in a broader context.[3]

In an attempt to study city systems, urban economist, regional scientists, and economic geographers observed two striking features about most urban systems: the first is the regularity of the size distribution of cities, whether the country is developed or a developing country, characterized by a hierarchal structure in which each county's urban system consists of relatively small numbers of large cities and a large number of small cities, which is characterized by the rank-size rule;[4] the second striking feature about city systems is their industrial composition. Particularly, most city systems are characterized by a hierarchal structure. In the top level of the hierarchy we have the largest city in the system, like New York, London, Paris, and Tokyo, which is characterized by a diversified industrial structure while in the bottom of the hierarchy we have a large number of small cities which are characterized by relatively specialized industrial structure.

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[2] Glaeser, Kallal, Scheinkman, and Shleifer (1992) found that diversity of industrial composition in cities stimulates urban growth; Henderson, Kuncoro, and Turner (1995) found that only new industries are attracted to diversified cities while mature industries grow faster in specialized cities.

[3] For a survey of growth and system of cities see Berliant and Wang in this volume and Abdel-Rahman and Anas (2003).

[4] The rank –size rule indicate that city size multiplied by its rank in the system is equal a constant, see Harris and Ioannides (2000).

The objective of this chapter is to provide a survey of recent development in the theory of system of cities that attempt to explain the forces behind the existence, the internal industrial structure, the city labor composition, and the interaction between cities in a network of city system. More precisely, the chapter addresses the following questions: *What are the main factors that lead to the formation of cities? When do cities specialize in production and when do they diversify? When do both specialize and diversify cities coexist? What is the role of trade in a system of cities? What determines the number and size of cities of different types in an economy? What are the factors that determine income disparities among different types of households?* These questions are addressed in a simple spatial general equilibrium model of a closed economy consisting of a system of cities. To simplify the basic model that will be used to review these issues we will impose some assumptions that facilitate such a task in a limited space. Thus, we will adopt the monocentric city model pioneered by Alonso (1964).[5] In this model the Central Business District is the only employment center in the city. Models of a system of cities that will be discussed are in the spirit of Mills (1967) and Henderson (1974), who typically consider two types of forces, forces that lead to a concentration of population and economic activities (*agglomeration forces*) and forces that lead to deconcentration (*dispersion force*). When these forces are balanced at the margin, the equilibrium city size is determined which imply the existence of an optimal city size. These types of models do not provide explanation of the spatial distribution of cities.

Since the pioneering woke of Christaller (1966) and Lösch (1940) urban theorists has been attempting to explain the special distribution, the hierarchal structure, and recently the growth city systems. In this endeavor two prototypes of models have evolved in the literature:

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[5] All researchers in the area have imposed most of the assumptions that we adopt.

the first is Alonso-Mills-Henderson type model, labeled as the New Urban Economics (NUE), that explicitly consider the internal structure of the city and ignore the agricultural land use and the special distribution of cities in the system over the landscape, the second is Fujita-Kurgan type model, that has been labeled the New Economic Geography (NEG), that explicitly consider the special distribution of cities and fixed agriculture land use but ignore the internal structure of the city.[6] This chapter will focus primarily on models of urban system in the spirit of A-M-H. The NUE models of system of cities has been influenced by: i) conventional urban economics emphasizing the tension between economy due to the concentration of population and economic activities and diseconomy due to spatial concentration; ii) the theory of industrial organization; iii) the theory of economic growth.

The first impact on NUE type model of system of cities is due to the initial theory of city size which emphasized the interaction between indivisibility in production, at the firm level, as the source of concentration and diseconomy due to commuting costs where the equilibrium city size is determined when these two opposing forces are balanced at the margin, Mills (1967) and Dixit (1973).[7] The second impact is by the theory of industrial organization occurred in a search for a more realistic model of city formation with multi-firm operating in the city. Marshallian externality, also known as the black box, Marshall (1890) and Chipman (1970), provided an operational model that can provide a story of urban agglomeration economy, Henderson (1974). Later on after the seminal contribution of Dixit and Stiglitz (1977) of the Chamberlin (1933) model of the product differentiation and monopolistic competition to the industrial organization literature it provided a tractable framework as well as a micro foundation of the black-box externality in the NUE models of system of cities.

[6] For a complete survey of the New Economic geography see Ottaviano and Thisse (2003).

Dixit and Stiglitz model also was the cornerstone on which the NEG was built upon. The key features in the NEG model were increasing returns together with linear space and fixed agriculture sector, and the Samuelson's iceberg transportation cost represented the essential ingredients of an operational special general equilibrium model. The third and relatively the most recent influential impact is by the theory of endogenous growth since most of the factors that have been identified as engine of economic growth such as knowledge spillover, human and physical capital accumulation are a phenomena that take place in urban areas. However, this influential theory has only affected the NUE type models but not the NEG.[8]

The organization of this paper is as follows: Section 2 present the internal structure of the city and household behavior as well as some important function that will be used in characterizing the equilibrium city size. Section 3 discusses various agglomeration forces and the institutional mechanism of city formation. Section 4 review models that result in identical cities. Section 5 present models of specialized system of cities with trade. Section 6 review models of specialized and diversified of cities within the systems; Section 7 is devoted to the modeling of a system of specialized cities with heterogeneous households. Section 8 develops Pareto efficient models of resource allocation in a system of cities and presents comparison between equilibrium and first best. Section 9 offers directions of future research.

2. The internal Structure of the city

In this section we will describe a monocentic city model to familiarize the reader with the internal structure of each city within the system. In this model it is assumed that each household resides at one location and has a single job that requires commuting to the central business

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[7] See also Dixit (1973) for an optimal city size model.

district (CBD) where all firms are located.[9] For simplicity, we postulate that each household consumes one unit of land. In addition, all households in the economy are assumed to have an identical utility function of the following Cobb-Douglas form:

$$U = x_1^{\alpha_1} x_2^{\alpha_2} \qquad (1)$$

where x_1 and x_2 are the quantities of privet goods consumed by a household. We now specify the budget constraint facing a household residing at distance r from the CBD as

$$P_1 x_1(r) + P_2 x_2(r) + R(r) + Wtr = Y \qquad (2)$$

where P_i is the price of x_i $i = 1,2$, R(r) is the unit land rent at distance r, W is the wage rate, t is the amount of time required to commute one unit distance, and Y denotes the household income.[10] Given that each household is endowed with one unit of time, then the net labor supply of a household residing at distance r is $1 - tr$. On the other hand, one can interpret this as a household working one unit of time and paying out of pocket commuting cost of Wt per unit distance. Both interpretations are consistent with the above budget constraint. From the first-order conditions of the maximization of (1) subject to (2), we obtain the demand for x_i as

$$x_i(r) = \alpha_i P_i^{-1}[Y - Wtr - R(r)] \qquad i = 1,2 \qquad (3)$$

Substituting (3) into (1), we derive the indirect utility function for a representative household in a given city as

$$V(P,W) = AP_1^{-\alpha_1} P_2^{\alpha_2}[Y - Wtr - R(r)] \qquad (4)$$

where $A = \alpha_1^{\alpha_1} \alpha_2^{\alpha_2}$. In terms of land ownership, two types of land ownerships that can be used in models of cities. The first type is the case of absentee ownership of land, where owners of

[8] For a survey of models of economic growth and system of cities see Abdel-Rahman and Anas (2003).
[9] This model has been adopted by most of the contributors to this literature.

land in the city live outside the city. The second type is public ownership in which each household owns an equal share of the land rent generated in the city in which he reside.[11] The absentee landlord case is not considered her because we are interested in a fully closed model where all money generated in the system is spent in the system. The reason for that is when we consider the first best problem in section 8 we adopt a global optimal for the economy and we want the equilibrium to be comparable to the optimal. Given the case of public ownership of land, the household income is given by

$$Y = \frac{ALR}{N} + W \tag{5}$$

where ALR is the aggregate land rent in a given city, and N is the size of the city. Recall that each household consumes precisely one unit of land. Thus, the total population of the city is given by

$$N = \int_0^b 2\pi r dr = \pi b^2 \tag{6}$$

where b represents the urban fringe distance for the city. The total commuting cost as a function of city size is

$$TCC = \int_0^b Wt2\pi rrdr = 2\mu N^{3/2} \tag{7}$$

where $\mu = t/3\pi^{1/2}$. Equilibrium requires that all workers in a given city achieve the same utility level. Hence, from (4) and (5), at each r we derive that $W - Wtr - R(r) = W - Wtb - R(b)$. Recall that for convenience, we normalize the opportunity cost of land to be zero so

[10] The assumption that commuting cost is in terms of time will be relaxed later where we will consider a monetary commuting cost.

[11] Other type of land ownership is if each household owns an equal share of the land rent generated in the economy. This will be equivalent to our approach if the economy has identical cities. But if the economy has more than one type of cities the efficiency will be distorted, see Harder and Pine (2002).

that $R(b) = 0$.[12] In equilibrium the land rent schedule is $R(r) = Wt[b - r]$. Using (6) and integrating the above land rent schedule, we can derive the aggregate land rent in each city as

$$ALR = \int_0^b R(r)2\pi r dr = \mu W N^{3/2} \qquad (8)$$

Equilibrium require that residential location cost must be the same for all r, thus the aggregate location cost of N households in the city is

$$ALC = \int_0^b [(R(r) + Wtr]2\pi r dr = 2W\mu N^{3/2} \qquad (9)$$

Observe that the ALC increase twice as much as the ALR. Substituting (5)-(9) into (4), we derive the indirect utility function for a representative household in a given city as

$$V(N, P, W) = AP_1^{\alpha_1} P_2^{-\alpha_2} W[1 - 2\mu N^{1/2}] \qquad (10)$$

It can be seen from the above equation that V(.) is increasing in household net labor supply, given by the term between brackets, and the wage but decreasing in prices. Furthermore it can be seen that the indirect utility is decreasing in city size, which represent the dispersion force resulting from the higher commuting costs resulting from the physical expansion of the city. The above equation is important for two reasons: first and as it will be seen later, it is essential in solving for city size: second because it illuminate the fact that *if there exist no benefit to city residence due to* concentration*, i.e., no agglomeration economy, the city will not exist.*

Inverting equation (10) with respect to W we can derive the inverse population supply function $Y(N, U) = \dfrac{AP_1^{\alpha_1} P_2^{\alpha_2} U}{[1 - 2\mu N^{1/2}]}$. This function represents the income necessary to attract an additional household to a city of size N so that all city residences would achieve the national utility level U. It can be seen that it is increasing in N, P, and U. Multiplying Y by N we can

[12] This assumption imply that there is no aggreculture land use in the economy.

derive the total cost, $C(N,U) = \frac{AP_1^{\alpha_1} P_2^{\alpha_2} UN}{[1 - 2\mu N^{1/2}]}$, which represents the total cost, residential and consumption costs, of maintaining U for a city with N residence.[13]

3. Agglomeration economies and city systems

Agglomeration forces in the city system literature can be classified into three main categories depending on whether they influence producer, consumer or producer or both. The former includes the various forces that lead to the geographical concentration of production activities such as (1) economies of scale at the firm level, leading to the formation of company towns, (2) localization economies, which is economy of scale at the level of the industry in a given city, leading to the formation of a specialized city, and (3) urbanization economies, which is scale economy at the level of the urban area, leading to the formation of a multi-product, diversified city. Localization economies, as indicated by Marshall (1890), the following quotations (p.271) describe the advantage of this externality:

> If one man starts a new idea, it is taken up by another and combined with suggestions of their own; and thus it becomes the source of further new ideas... Again, the economic use of expensive machinery can sometimes be attained in a very high degree in a district in which there is a large aggregate production of the same kind,.. a localized industry gains a great advantage from the fact that it offers a constant market for skill. Employers are apt to resort to any place where they are likely to find a good choice of workers with the special skill which they require; while men seeking employment naturally go to places, where there are many employers who need such skills as theirs and where therefore it is likely to find a good market.

[13] For the derivation of the population supply function and the total cost function in with variable lot size see Fujita (1989) Chapter 5.

Most of the advantage mentioned by Marshall whether it is in the labor market or intermediate inputs or in the information spillover, are all intra-industries. In other words, they are due to concentration of firms in the same industry in a given urban area defined by Weber (1929) followed by Hoover (1948) as localization economies. Lucas (1988) and Romer (1986) identified these types of externalities as the engine of economic growth. We can identify the sources of these externality as (1) the *information externalities* stemming from interaction among agents and face-to-face communication, which enhance productivity and foster innovation,[14] (2) the access to the wide range of *specialized intermediate input*, (3) *matching of labor with heterogonous skill in the labor market* which reduces the search cost, (4) *matching of used assets in the capital market* which enhances the salvage values of assets from failed projects in large cities, and (5) *acquisition of task-specific skill*, human capital, which enhances productivity.[15]

On the other hand, urbanization economies result from (1) *cross products technological externalities*, Jacobs (169),[16] (2) the use of *shared specialized intermediate input or local public good in production*, (3) *economies of scope* in production, (4) *research and development of proto type.* On the consumer side, we find the forces leading to the concentration of population through improvement in utility such as, (1) the existence of *natural amenity* and (2) the provision of various *local public goods*.

Finally, models of agglomeration economy on the consumer and the producer side in the literature are due to product differentiation and monopolistic completion in which *the desire of*

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[14] The classification of agglomeration in this paper is in the sprit of Hoover (1939) and Weber, (1929) who introduced the concept.

[15] See Duranton and Puga (2003) for a survey of micro foundation models of these externalities.
[16] See Jacob (1969) for an argument on the impact of interaction on creativity in production.

consumers to consume large variety of goods and services together with economy of scale result in the formation of city, Dixit and Stiglitz (1973).

3.2 Equilibrium System of cities

Models of city systems can be classified, from the point of view of industrial composition of cities, into three main groups: (1) models which result in a specialized system of cities, (2) model which result in a diversified system of cities, (3) models which result in co-existence of specialized and diversified cities. In the former, the main issues to be addressed are the factors that determine the size and the number of cities within the system. In the latter, the issues to be addressed are the factors that determine the structure of city systems, the factors that determine the cities' industrial composition, as well as the sizes and the number of each type of city within the system.

Furthermore, model of system of cities can be classified, with respect to market structure within each city in the system into three groups: (1) models in which the market structure is perfectly competitive, (2) models in which the market structure is monopolistically competitive, (3) models in which both perfectly competitive as well as monopolistically competitive.

Moreover, models of system of cities can be classified from the point of view of intercity trade into: (1) models in which there is no intercity trade, (2) models in which there is intercity trade at positive or zero transportation costs.

In addition, models of city systems can be further classified, from the point of view of the types of worker/households, into two types: (1) models of identical households, in which all households are assumed to have identical income; (2) models with a multi-type household, in which households are assumed to have different incomes.

Finally, one can classify model of system of cities based on the type of institutional mechanism underlining the formation of cities in the system as (1) city formation by local government or community, (2) cities formed by profit maximizing developer, (3) city formed by atomistic agent.

3.3 Institutional city formation Mechanisms

The first institutional mechanism of city formation is by local government, Henderson (1974). The role of the local government is to set up the city by providing public good or basic infrastructure needed for the development of the city and collect any tax or provide any subsidy. Local government acquires the land needed for the city development and rent the land to households at a competitive market. Given that households are identical, they must achieve the same utility level. Thus, the objective of the local government is to maximize the utility of the representative household in the city by choosing the level of provision of public good (if needed) and the city size. Furthermore, local government must balance the budget.

The second mechanism is when a profit maximizing developer form and manage the city. It is assumed that the developer owns all the land required for city development and then sublet the land for city residence in a competitive land market. There are large numbers of potential sites for city development in the economy. Each developer controls one sit that he uses for city development. Furthermore, it is assumed that the number of cities in the economy is lager and that each city is small relative to the national market. Thus, developers are competitive in the output and the labor markets. Therefore developer behaves, as is a utility and price-taker in the national market. The objective of the developer is to maximize profit from the city development defined as the deference between the revenue from the city and the cost of maintaining a national utility level U. The developer chooses the number of residents in such a way that each resident will not do worse than achieving the national reservation utility level. If city-developer makes profit, then new developers will enter the city-development market and set up new cities. Competition among city-developers would result in zero profit in equilibrium. The above two mechanisms will be equivalent under the assumption that the city-development market is contestable and that there is no limit to the number of cities.[17] Thus, both city formation mechanizes would result in the same city size.[18]

The third institutional city formation framework is the self-organization.[19] In this framework the city size is determine through the defection of atomistic agent. Each agent is assumed to be small and behave so as to maximize his own profit or utility. It is assumed that household/firm can move freely and costly between cities so as to maximize utility/profit. If the utility of a representative household is strictly concave in city size, as it will be shown later, as the size of the city increase the utility will increase and household will continue to move into the city. [20] In this framework, all city sizes from the peck of the utility and beyond are stable equilibrium. Thus, this city formation mechanism results in multiple equilibrium city sizes. This is unlike the previous cases of developer or utility maximizing community city formation mechanism where the city size that correspond to the pick of the utility represent a unique equilibrium city size.

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[17] Helsley and Strange (1994) showed that in a game-theoretic framework with a fixed finite number of cities that the system of cities would be inefficient. Henderson and Thisse (2001) examined a strategic community development model of differentiated communities in which the number of communities is endogenous.

[18] For game theoretic approach to city formation mechanism see Helsley and Strange (1994). See also Henderson and Thisse (2001) for strategic community development with households differentiated by income.

[19] See Becker and Henderson (2000) for a comparison between formation of cities by large agent and by atomistic defection.

[20] One can specify a model in which the indirect utility function is strictly convex see Fujita (1989).

In most of Henderson work he emphasized the roll of developers or large agent in setting up cities in his work. However, realistically city formation is a mix of large agent first starting up cities followed by independent agent or small developers. On the other hand, NEG models take the other extreme in which atomistic agents form cities.

4. Identical cities without trade

In this section we review models of a city system in which we have identical households in the economy and in which the industrial composition of cities within the system is predetermined. Furthermore, within this framework no interactions occur between cities except through costless migration.[21] The problem that will be considered is of a closed economy consisting of a system of identical cities, where the member of cities is endogenous. We postulate an economy sufficiently large so that we have a large number of cities. Thus, we treat the number of cities as a continuous variable. We will present five models of city formations. The first model is based on the provision of local public good [Flatters, Henderson, and Mieszkowski (1974)]. The second model is based on external economy of scale [Chipman (1970)]. The third model is based on the desirability of a final good industry to use differentiated intermediate input in production [Ethier (1982)]. The forth model is based on consumer preference for variety [Dixit and Stiglitz (1977)] in the consumption of nontraded goods.[22] Finally, we consider a model of a system of specialized cities in which each city produces a differentiated product and trade occurs among cities. The main issues that will be discussed are the factors that determine city size and the number of cities in the economy.

Let us first describe the common framework that we use to review this literature. We

[21] All system of city models considered in this survey assumes costless migration between cities.

consider a closed economy consisting of a system of circular cities spreading over a flat, featureless plane. The economy is populated with $\overline{N}$ identical households where each one is endowed with one unit of labor (this assumption will be relaxed later in section 7). Each household is free to choose the city in which to reside and work. Households migrate between cities, at zero migration cost, in search for the highest utility possible. Two final goods, X_1 and X_2, are produced within the system. Cities are formed in this economy by local governments. A local government of each city rents the land for the city at the opportunity cost, which is assumed to be zero. Then the local government sublets the land to households at the market rent. Each city government chooses the population size of the city, N, and the level of public good if provided in the city such that the utility of a representative household is maximized.

4.1 Public Good

Suppose that the city is formed due to the provision of local public good financed collectively by city residence [Flatters, Henderson, and Mieszkowski (1974), Stiglitz (1977), Arnott (1979), Arnott and Stiglitz (1979), and Kanemoto (1980)]. We will assume that the city produces two private goods, $X_1$and X_2 and a local public good Z (city good). The consumer has a utility function given by $U = x_1^{\alpha_1} x_2^{\alpha_2} Z^{\alpha}$. The private good is produced competitively under constant returns, with labor as the only input in production, $X_i = \eta_i L_i \; i = 1,2 \quad \eta_1 = 1$. Given that good X_1 is the numeraire, $P_1 = 1$. The public good is produced with the use of the private

[22] See Stahl (1983) for an initial work on the impact product variety in consumption on migration.

good X_1. A resident pays a lump sum tax, T, to finance the public good. $Z = TN$. Thus, given (10), the indirect utility is

$$V = AP_2^{-\alpha_2}[1-2\mu N^{1/2} - N^{-1}Z]Z^{\alpha} \qquad (11)$$

Now let us solve the problem in two steps. In the first step we choose Z for a given population size N. This will result in the following first order condition

$$\frac{\partial V}{\partial Z} = \alpha \ [1-2\mu N^{1/2} - N^{-1}Z]Z^{1} - N^{-1} = 0 \qquad (12)$$

The above condition is the Samuelson condition for the optimal provision of public good. This condition requires the equality between the marginal cost of the public good, 1, and the marginal benefit, given by the sum of the marginal rate of substitution. Solving (12) for Z and substituting in (11) we have

$$V = AP_2^{-\alpha_2}\left(\frac{1}{1+\alpha}\right)^{1+\alpha} \alpha^{\alpha} N^{\alpha} \ [1-2\mu N^{1/2}]^{1+\alpha}$$

Maximizing with respect to N, we have

$$\frac{\partial V}{\partial N} = -\mu N^{1/2} + \frac{\alpha}{1+\alpha}(1-2\mu N^{1/2}) = 0 \qquad (13)$$

Multiplying though by N we have, condition for the Henry George Theorem, which require that the cost of provision of the public good be financed by confiscation the aggregate land rent in the city. Thus, the Pigouvian tax, T, will be imposed on each residence such that the total tax revenue is equal to the aggregate land rent. Condition (12) and (13) can be solved for the equilibrium city size, N^*, and the equilibrium provision of public good as

$$N^* = \left[\frac{\alpha}{[1+3\alpha]\mu}\right]^2 \qquad Z^* = \left[\frac{\alpha}{[1+3\alpha]\mu^{2/3}}\right]^3 \qquad (14)$$

Proposition 1. *The equilibrium city size and the equilibrium level of provision of public good are increasing in the share parameter of the public good and decreasing in commuting cost.*

It can be seen from the above proposition that as $\alpha \rightarrow 0$ then $Z^* \rightarrow 0$ and $N^* \rightarrow 0$. In other word, if the public good is not provided the city will not exists.

Assuming a very large economy, the stable equilibrium number of cities in the economy, m^*, is given by $m^* = \frac{\overline{N}}{N^*}$. Observe that this is equilibrium is stable since all households in the economy will achieve the highest possible utility level and thus no movement of population between cities would improve the welfare. To see this suppose that some local government would form cities larger than N^* in this case atomistic defection of households from these cities to other smaller cities would improve their utility and thus larger cities cannot be sustained. On the other hand, suppose that cities are smaller than the N^* in this case household would improve their utility by increasing city size. Thus, the only stable city system is when the population of all cities in the system is N*.

Proposition 2. *A city system exhibits constant return to aggregate population growth.*

The above result emphasize that as the total population of the economy grow the number of cities would grow at the same rate. Thus, the economy would accommodate the new population by spawning new cities of size N*.

4.2 Marshallian Externality

Now we will consider a model in which cities are formed due to an external economy of scale [Henderson (1974), Kanemoto (1980), and Upton (1981)]. Suppose that both x_1 and x_2 are private goods where industry 1 is produced by a production function subject to external economy of scale while industry 2 is produced with CRS as in section 4.1. Furthermore suppose that both good are nontraded good between cities. Thus, this economy will result in a system of identical cities where each city produces both goods X_1 and X_2 (we will call this a system of diversified cities). The aggregate production function is $X_1 = L_1^{1+\varepsilon_1}$ while the aggregate production function for X_2 is the same as in the previous section. Given that workers are paid their privet marginal product, the wage of workers in industry 1 and 2 are $W_1 = L_1^{\varepsilon_1}$ and $W_2 = P_2$. The objective of the city developer is to maximize the utility of a representative household in the city. Assuming that full employment will prevail in every city, then the labor supply for each industry is given by

$$L_1 + L_2 = N - 2\mu N^{3/2} \tag{15}$$

All cities in the economy are identical. Therefore, the aggregate demand of good X_2 by each city is given by integrating (3) as

$$AD_2 = P_2^{-1}\alpha_2 \int_0^b [W - Wtr + (ALR)N^{-1} - R(r)]dr \tag{16}$$

From (5)-(8) and by equating the aggregate demand to the aggregate supply, we have

$$L_2 = \alpha_2[N - \mu N^{3/2}] \tag{17}$$

Thus, the net labor supply is allocated between both industries proportional to the share parameter in the utility function. Substituting $W_1 = L_1^{\varepsilon_1}$, (15) and (17) into (10) we have

$$V = A\alpha_1^{\varepsilon_1} P_2^{-\alpha_2} N^{\varepsilon_1}[1 - 2\mu N^{1/2}]^{1+\varepsilon_1} \tag{18}$$

Given that local government is price taker in the output market, it maximizing the above indirect utility with respect to N and solving the first order conditions we have

$$N^* = \left[\frac{\varepsilon_1}{(1+3\varepsilon_1)\mu^{3/2}}\right]^2 \tag{19}$$

Proposition 3. *The equilibrium city size is increasing in the external economy of scale parameter.*

Observe that if $\varepsilon_1 \rightarrow 0$ the city will not exists. Furthermore, comparing (14) and (19) we can conclude that both the external economy of scale model and public good model would result in the same city size if the parameters ε_1 *and* α were properly chosen.

4.3 Differentiated intermediate input

Consider an economy producing an homogenous good X_1 with the use of labor and a differentiated intermediate input, Ethier (1982), model as a micro-foundation of the black box approach to external economy of scale that has been used in the city size model, Abdel-Rahman and Fujita (1990). Here we explicitly model the availability of specialized services, such as repair and maintenance services, engineering and legal support, transportation and communication services, and financial and advertising services that have been used as the major cause of external economy of scale. Furthermore, these services constitute a significant share of employment in almost all industrialized countries see Hansen (1990) for the US case]. Thus, to understand city formation and industrial composition, we have to take into consideration the service sector. The central idea behind the model is that increasing returns to scale and the desire for variety of intermediate input provide the basic source of industrial agglomeration and city formation [see Abdel-Rahman and Fujita (1990)]. The production function of the final good is given by

$$X_1 = L_1^{\beta_1}\left[\left(\sum_i^n q_i^{\rho 1}\right)^{1/\rho_1}\right]^{(1-\beta_1)} \qquad \beta_1, \rho_1 \in (0,1) \quad (20)$$

where q_i is quantity of differentiated intermediate input i *and* L_1 is the quantity of labor used in the production of X_1. While the production function of X_2 is as in the previous section. The problem of the firm is to choose inputs L1 and $\{q_i\}$ so as to maximize its profit given by $\pi_1 = X_1 - WL_1 - \sum_{i=1}^{m} P_i q_i$. From the first order conditions we have

$$L_1 = \beta_1 X_1 W \tag{21}$$

$$q_i = [(1-\beta_1) X_1 \sum_{l=1}^{n} q_i^{\rho_1} \; p_i^{-1}]^{1/(1-\rho_1)} \tag{22}$$

The behavior in the differentiated service is as presented in the previous section. Again following Dixit and Stiglitz, we assume that each of the n_1 products is produced by a single firm, and by an increasing returns technology

$$L_{qi} = f_1 + c_1 q_i \tag{23}$$

where f_1 is the fixed labor input, plus a marginal labor input, c_1 is the marginal labor input per unit produced. All firms in city type j pay the same wage, W , and are perfectly competitive in the labor market. In the output market, the firms are monopolistically competitive and achieve Chamberlin equilibrium [Chamberlin (1933)]. This imperfect competition in the output market is the basis of the market failure in this model. Because the final product's demands for the intermediate input are symmetrical and there is also symmetry among the many firms, the Cournot-Nash markup condition is approximately

$$p_{1q} = Wc_1 \rho_1^{-1} \tag{24}$$

where ρ_1 is the price elasticity of demand for each product. Hence, the equilibrium product prices are. From the zero profit condition, we can derive the equilibrium quantity of each intermediate input as

$$q_1 = \frac{f_1 \rho_1}{c_1(1-\rho_1)} \qquad (25)$$

Substituting (24) into (22) we can derive the equilibrium employment in each form in the intermediate input sector as

$$L_q = f(1-\rho)^{-1} \qquad (26)$$

Full employment in a given city is given by

$$N - 2\mu N^{3/2} = L_1 + L_2 + n_1 L_{1q} \qquad (27)$$

The RHS of (27) is the aggregate labor demand and the LHS is the aggregate labor supply in each city. Substituting (17) and (26) into (27) we have

$$L_1 + n_1(1-\rho_1)^{-1} f = \alpha_1[N - \mu N^{3/2}] \qquad (28)$$

From (21), (25), (28) and the zero profit condition in the intermediate inputs we have

$$L_1 = \alpha_1 \beta_1 (N - \mu N^{3/2}) \qquad (29)$$

$$n_1 = \alpha_2 f^{-1}(1-\rho_1)(1-\beta_1)(N - \mu N^{3/2}) \qquad (30)$$

The reason for the formation of cities in this economy is the existence of economies of scale in the production of each intermediate good. On the other hand, the reason for the concentration of firms is the desire of industry X_1 to employ a large variety of intermediate services given that such services are non-traded within the urban system. It can be seen that the number of intermediate services is strictly concave in the population of the city as in (30). It can then be shown that the wage prevailing in the city is given by $W(n_1) = \beta_1^{\beta_1}(1-\beta_1)^{(1-\beta_1)} c_1^{-(1-\beta_1)} \rho_1^{(1-\beta_1)} n_1^{(1-\rho_1)(1-\beta_1)/\rho_1}$. *This implies that the larger the variety of* *intermediate goods the higher the productivity of labor in industry X_1.* Substituting (30) into $W(n_1)$ we have

$$W(N) = B_1(N - \mu N^{3/2})^{(1-\rho_1)(1-\beta_1)/\rho_1} \qquad (31)$$

where $B_1 = \beta_1^{\beta_1}(1-\beta_1)^{(1-\beta_1)/\rho_1} c_1^{-(1-\beta)} \alpha_1^{(1-\rho_1)(1-\beta_1)/\rho_1} f_1^{-(1-\rho_1)(1-\beta_1)/\rho_1} \rho_1^{(1-\beta_1)} (1-\rho_1)^{(1-\rho_1)(1-\beta_1)/\rho_1}$

Proposition 4. *The wage equation as a function of city size is structurally the same as the wage equation in the case of external scale economy.*[23]

This relationship is supported by empirical evidence [Hansen (1990)]. Furthermore the wage is strictly concave in city size. This is the reason behind city formation in the presence of product variety in intermediate goods. *It is interesting to note that this model generates a wage equation which is structurally the same as the one assumed in the Marshallian externalities model* [see Abdel-Rahman and Fujita (1990)]. In other words, the product differentiation model is used as a micro-foundation for Marshallian externalities. Substituting the (31) into (10), we derive the indirect utility function as a function of city size as

$$V(N) = AB_1 N^{(1-\rho_1)(1-\beta_1)/\rho_1} (1 - 2\mu N^{1/2})^{[(1-\rho_1)(1-\beta_1)/\rho_1]+1} \qquad (32)$$

As in the previous model the local government maximizes the utility of a representative household by choosing city size. It can be shown that the above utility function is strictly concave in n with a unique maximum, which represents the equilibrium size of a given city in the economy like the case of *Marshallian externality* Abdel-Rahman and Fujita (1990). The increasing segment of the indirect utility is due to the productivity gain resulting from increasing

[23] This equation provides a micro-foundation for the existence of localization economies.

the range of product variety, i.e., the agglomeration force dominates. On the other hand, the decreasing segment is due to high commuting costs resulting from the physical expansion of the city, i.e., the dispersion force dominates. The equilibrium city size is given by

$$N^* = \left[\frac{(1 - \beta_1)(1 - \rho_1)}{[\rho_1 + 3(1 - \beta_1)(1 - \rho_1)]\mu} \right]^2 \tag{33}$$

Proposition 5. *The equilibrium city size increases with the degree of preference for variety, i.e., the smaller the parameter* ρ_1 *and the share parameter for the differentiated input in the production function,* $(1-\beta)$.

The intuition behind this result is that the higher the desire of the final good industry for variety the larger the number of firms. Furthermore the larger is the share of the intermediate input in the production the higher the use the more intensive the use of intermediate input in production. Here also, the total number of cities would be given as $\frac{\overline{N}}{N^*}$.[24]

Now suppose that the production function of X_2 is given by

$$X_2 = L_2^{\beta_2} \left[\left(\sum_i^{n_2} q_i^{\rho_2} \right)^{1/\rho_2} \right]^{(1-\beta_2)} \qquad \beta_2, \rho_2 \in (0,1) \tag{34}$$

and if the intermediate inputs are non-traded, then both industries share the use of the same differentiated services we have the following. Thus shared intermediate input result in a system of identical diversified cities.

[24] It can be seen that the equilibrium city size is decreasing in ρ_1, α_1 and t.

Proposition 6. *This economy would result in a system of diversified cities where all cities in the economy will produce both consumption goods as well as the corresponding differentiated intermediate services.*[25]

Thus, sharable input represents a reason for the formation of diversified cities in the economy.

4.4 Differentiated consumption good

Next we will discuss the case of a differentiated nontraded consumption good, Dixit and Stiglitz (1976). Hobson (1997) and Abdel-Rahman (1988) among others adopted Dixit and Stiglitz model into a special context where the desire of households to consume a variety of nontraded differentiated services represents one of the main reasons for the existence of large cities. Consider the case in which x_1 in (1) is a sub-utility of the CES form.[26] Then (1) would be

$$u = \left(\left[\sum_{i=1}^{n} q_i^{\sigma} \right]^{1/\sigma} \right)^{\alpha_1} x_2^{\alpha_1} \qquad (35)$$

where q_i is the quantity of the variant i of a nontraded differentiated good or service such as restaurants or movie theaters. As $\sigma \to 1$, products become close to perfect substitutes and households derive less utility from product variety. Alternatively, as $\sigma \to 0$, products become highly differentiated and households derive more utility from product variety. The budget constraint for a household is now given by $x(r) + \sum_{i-1}^{m} P_i z_i(r) + R(r) + Wtr = Y$. From the maximization of subject to the above constraint we derive the household demand for each differentiated service as

[25] For this model see Abdel-Rahman (1990).
[26] See also Rivera-Batiz (1988) for Dixit and Stiglitz model in regional context.

$$q_i(r) = \{\alpha_1 P_i^{-1} z^{-\sigma}[Y - Wtr - R(r)]\}^{1/(1-\sigma)} \qquad (36)$$

The demand for x is as in (2). Substituting (36) and (3) into (10) we derive the indirect utility function is $V = A\xi^{-(1-\alpha_1)}W[1 - 2\mu n^{1/2}]$, where $\xi = [\sum_i^n P_i^{-\sigma/(1-\sigma)}]^{-(1-\sigma)/\sigma}$. Each of the differentiated services, q_i, is assumed to be produced with an identical production process as in the previous section. Good X_2 is produced as before by labor only with a simple constant-returns-to-scale technology. Assuming that full employment prevails in each city, the total population of a representative city is given as $L_2 + nL_1 = N - \mu N^{3/2}$. All cities in the economy will be identical. The employment in industry 2 will given as in equation (17) while the employment in each differentiated firm will be given as in equation (26), thus the full employment condition we have

$$n = f^{-1}(1-\sigma)\alpha_1[N - \mu N^{3/2}] \qquad (37)$$

Observe that the number of variety is strictly concave in city size. This suggests that the formation of large cities involves a substantial amount of product diversity increasing product diversity is a sufficient condition for the formation of larger cities. This result is supported by casual observation that all large cities offer a large variety of goods and services. Local government form cities by choosing the city size that maximizing the utility of a representative household

$$V = CN^{(1-\sigma)\alpha_1/\sigma}[1 - \mu N^{1/2}]^{1+\frac{(1-\sigma)\alpha_1}{\sigma}} \qquad (38)$$

where $C = A c^{-\alpha_1} \sigma^{\alpha_1}((1-\sigma) f^{-1})^{(1-\sigma)\alpha_1/\rho}$. Observe that this function is strictly concave in N, which shows that product variety in the nontraded differentiated service is sufficient for the formation of multiform city. The increasing segment of the indirect utility is due to the increase in product variety, i.e., the agglomeration force dominates. On the other hand, the decreasing segment is due to high commuting costs resulting from the physical expansion of the city, i.e., dispersion force dominates. Maximizing (30) with respect to n we can derive the equilibrium size of a representative city as follows:[27]

$$N^* = \left[\frac{\alpha_1(1-\sigma)}{\{\sigma + 3\alpha_1(1-\sigma)\}\mu} \right]^2 \qquad (39)$$

Proposition 7. *the equilibrium city size is increasing in* σ *and* α_1.

Thus the higher the desire of consumer for variety and the higher the share of differentiate good in the utility function the higher the number of variety in the city and thus the larger is the city size. The equilibrium number of cities is given by $\frac{\overline{N}}{N^*}$, since all cities in the economy are identical. From the above models we cal conclude the following;

Proposition 8. *All of the above four models result is structurally the same indirect utility function of the form* $V(N) = AN^a(1-2\mu N^{1/2})^{1+a}$ *and the same city size of the form* $N = \left[\frac{a}{(1+3a)\mu} \right]^2$.

However, unlike cities that are formed due to public good or Marshallian externality, models of product variety on the consumption side or on the production side if $a \to 0$, N^* will not be zero. This is since the city can still be formed due to internal return to scale in a single firm in sector q.

Helsley and Strange (1991) presented non-spatial model that would result in agglomeration. They adopted a matching and search model for the capital market in a non-spatial model. The idea hinges upon the assumption that salvage value of assets in large cities is

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[27] It can be seen that the equilibrium city size is decreasing in $\alpha_1, \sigma, and t$.

higher than in small ones. The reason is that a bank allocates credit to projects that have addresses in a characteristic space and if the project fails then the bank repossesses the asset. The second best use of an immobile and specialized asset is more valuable where the density of possible uses is greater, as it is in large cities.

5. Specialization and trade

In all of the models presented in the previous section each city in the economy produce all of the good consumed. Now we will analyze problems of equilibrium resource allocation in a closed economy consisting of a system of different types of cities, where the member of cities is endogenous and in which cities interact with other cities in the system though trade. Two types of models will be considered; one type of model considers trade with costless transportation costs while the other type of model considers trade with an iceberg transportation cost. In these models cities in the system will specialized in production of a particular good as lone as there is no benefit of producing more than one good in the same city and city can trade with other cities in the system. This is because if cities can trade and no benefit exists due to diversity, locating more than one industry in the city would increase the population and commuting cost and thus result in lower utility for city residence.

Henderson (1974) presented the first model in which trade with costless transportation cost and specialization accurse in a system. We will discuss a version of this model in which cities are formed due to an external economy of scale. Suppose that both X_1 and X_2 are private goods where $X_i = L_i^{1+\varepsilon_i} \quad i = 1,2$. Thus, this economy will result in a system of specialized cities where one type of city will specialize in the production of good X_1 while the other will specialize in the production of good X_2. Given that workers are paid their privet marginal product, the wage is $W_i = P_i L_i^{\varepsilon_i}$, where $P_1 = 1$. The objective of the city developer is to maximize the utility of a representative household in the city. Assuming that full employment will prevail in every city, then the labor supply for each industry is given by

$$L_i = N_i - kN_i^{3/2} \qquad i = 1,2 \qquad (40)$$

The indirect utility for a household in city type x_1 will be given as in section 4.2, while the indirect utility for a household in city type x_2 will be given as

$$V_i = AP_2^{\alpha_1} N_1^{\varepsilon_1}[1 - 2\mu N_i^{1/2}]^{1+\varepsilon_i} \; i = 1,2 \qquad (41)$$

Maximizing the above indirect utility with respect to N and solving the first order conditions we have the equilibrium city size 1 and 2 as in (19). Assuming a very large economy, the stable equilibrium number of cities N_i^*

$$\frac{m_1^*}{m_2^*} = \frac{\alpha_1 N_2^*}{\alpha_2 N_1^*} \qquad (42)$$

Proposition 9. *The relative number of cities in the economy is increasing in the demand parameter and decreasing in city size, and independent of the total population.*

Given that households are identical, then all households in the economy will achieve the same common utility level.[28] Observe that this is equilibrium a stable equilibrium since all households in the economy will achieve the highest possible utility level and thus no movement of population between cities would improve the welfare.[29]

Now we will consider another type of costless trade model. Specialization in this context is a result of the desire of each final good industry to uses different differentiated inputs in production. Thus, one type of city specializes in the production of good X_1 and a group of differentiated input as in section 4.3 while the other type of cities specializes in the production of

[28] The equal utility condition is used to solve for the equilibrium price of good z in terms of good x.

[29] Wilson (1987) considers another reason for specialization in a non-spatial model where communities are formed due to the provision of public good. The economy produce two tradable private goods produced under constant

good X_2. The production function of the final good is given by (20) and (34). The behavior of the firms in the differentiated intermediate input/service is as presented in the section 4.3. Again following Dixit and Stiglitz, we assume that each of the n_i products is manufactured by a different firm, and by an increasing returns technology requiring a fixed labor input, f_i where $i = 1,2$, plus a marginal labor input, c_i where $i = 1,2$, per unit produced. The above model can generate cities of different sizes. For example *if the economy produces two final goods where each good uses a different group of nontraded differentiated services, then the economy generates two types of cities, each specializing in the production of one final good and the group of differentiated services used in its production.* This will be the case as long as no benefit can result from the location of both industries within the same city.

Henderson and Abdel-Rahman (1991) adopted Dixit and Stiglitz model to examine the formation of a system of cities where each city specialized in the production of a single differentiated good traded at zero transportation cost.[30] The purpose is to explain national economies of scope arising from product diversity. In other words, large nations are able to provide a larger variety of goods. In this framework, the reason for the formation of cities in the economy is the presence of economies of scale in the production of each variant, as given by (29). Given that a differentiated product is traded at zero transportation cost, each city will specialize in the production of one variant and the production of the nontraded good. This is because producing more than one differentiated good in a given city will increase commuting costs without generating any productivity gain. Production sectors are the same as in the previous section. However, full employment in each city requires that

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returns with land and labor. In this framework communities will specialize in production of privet good due to difference between privet good in labor intensity in of the use of labor in production.

[30] Hochman (1997) examined the same model with variable lot size.

$$N - 2\mu N^{3/2} = f + cq + L_x \qquad (43)$$

Solving for q and L as in the previous section and substituting into (43), we have

$$f(1 - \rho)^{-1} = \alpha_2[N - \mu N^{3/2}] \qquad (44)$$

The above equation determines the equilibrium city size. Thus, we can the following

Proposition 10. *Equilibrium would result in a system of identical cities where each city produce one differentiated good and x_2.*

Observe that if the utility were a function of only the differentiated product then the model would result in a system of company towns as in Henderson and Abdel-Rahman (1991).

Proposition 11. *National economy of scope will increase with population growth.*

Population growth in the above system would result in more cities and thus more differentiated products. This would result in higher utility since consumer derives more utility variety as implied by the utility function.

6. Specialization versus diversification

This section survey models that generate cities of different types, sizes, and industrial composition. The fundamental questions that are addressed in these types of models is to explain the reasons behind the formation of cities of different industrial composition as well as the coexistence of specialized and diversified cities. Four types models are reviewed in this section. In the first model, the formation of diversified cities is cross product technological externalities. The second model, the reason for the formation of diversified cities is economy of scope in production. The third type of model, the reason for the formation of diversified cities is intercity transportation costs. Finally, in the fourth type of model, the reason for the formation of diversified cities is the product innovation. These models can be classified into two group;(1) models that result in either specialized or diversified cities, (2) models that result in specialized, diversified, and mixed system. Since almost all systems of cities that we observe in developing and developed countries of diversified and specialized cities, models that result in mixed city systems are the most realistic.

Cross product externality

The first model that addressed the formation of diversified cities and the coexistence of diversified and specialized cities is Abdel-Rahman (1990). The model is of two sectors and two cities embedded in an open economy. Both goods X_1 and X_2 are traded at zero transportation costs. Both good X_1 and X_2 are produced with the following production functions

$$X_{1i} = f(L_1, L_2)L_{1i} \qquad f'_1, f'_2 > 0 \qquad (45)$$

$$X_{2i} = g(L_2)L_{2i} \qquad g'_2 > 0 \qquad (46)$$

where $L_1 and L_2$ are the quantity of labor in industry X_1 and X_2 in a given city while $L_{1i} and L_{2i}$ are quantity of labor in firm j in industry 1 and 2 respectively. Thus, industry 1 has *urbanization economy,* (Jacobs (1969), because it reflects external economies of scale that operate across industries in the same city. Industry 2 has *localization economies*, Marshall (1890). The author examined a system consisting of a diversified city and a city specializing in industry 2.[31] The household side of the model is as in section 2 above.[32] This framework enables us to analyze a system of two types of cities. The formation of a diversified city producing both goods X_1 and X_2 is due to the cross product externality. While the reason for the formation of a specialized city, producing only X_2 is Marshallian externality. Some of the main results of the model are; first, the diversified city is larger than the specialized one if at least one of the two industries exhibits external diseconomy of scale, second, the specialized city will have more employment

[31] Jacobs (1969) stressed the important of this inter-industry spillover as the force underlining the process of innovation in which the automobile industry emerged from a diversified economy.

in the industry in which the city specialized in compare to the diversified city. However the model assumed the coexistence of the diversified and the specialized city rather than derive that condition for that endogenously. Furthermore the model is a partial equilibrium where the number of cities is given endogenously.

Transportation costs

Next we discuss models in which the number of cities as well as the industrial composition is determined endogenously. In other words, these models would lead to different equilibrium configurations, i.e., a different city system, under each set of parameters' values. The first model by Abdel-Rahman (1996) uses product variety in the intermediate good sector, which was introduced in section 4. The model generates two equilibrium configurations: (i) pure specialization, in which each city specializes in the production of one group of intermediate producer services and one final good; and (ii) pure diversification, in which all cities in the economy produce two groups of intermediate producer services and two final goods. In the context of this model, cities specialize in the production of a particular final good. The reason for that is *the desire of the final good industry to take advantage of productivity gains offered by using a wider variety of non-traded differentiated services* [Abdel-Rahman and Fujita (1990)]. On the other hand, the reason for diversification is *the high intercity transportation cost* of the final goods.

The production function X_1 and X_2 are given as in (20) and (34) where X uses a group of differentiated services q_1 while X_2 uses a group of differentiated services q_2. Thus, the production sectors are the same as presented in section 4.3. We assume Samuelson's iceberg transportation cost for both traded goods. In this context, when one unit of the good is

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[32] The author used a variable lot size model and a general functional form utility instead of the fixed lot size and a Cobb-Douglas utility function as in section 2.

transported from one city to another, regardless of the distance between them, only a given fraction, $\tau_{1i} < 1 \, if \quad i \neq 1$ and $\tau_{2i} < 1 \, if \quad i \neq 2$, of this good will arrive. Hence, transportation costs are an inverse function of τ_i. The budget constraint for a given household at distance r_d from the CBD in a given diversified city of type d is given as in (2). While the budget constraint for a household at distance r from the CBD in specialized city of type i=1,2 is given by

$$\tau_{1i}^{-1} x_1 + P_2 \tau_{2i}^{-1} x_2(r_i) + R(r_i) = Y_i - W_i t r_i \qquad i = 1,2 \tag{47}$$

where $\tau_{22}, \tau_{11} = 1$. In pure specialized equilibrium, we solve for the indirect utility of each type of city as

$$V_i = AB_i \tau_{i1}^{\alpha_1} \tau_{i2}^{\alpha_2} P_2^{-\alpha_2} N_i^{(1-\rho_i)(1-\beta_i)/\rho_i} (1 - 2\mu N_i^{1/2})^{[(1-\rho_i)(1-\beta_i)/\rho_i]+1} \tag{48}$$

Thus, from (48) we solve for a unique equilibrium utility level for the specialized system. In equilibrium utility must be equalized between city type 1 and 2, thus we can solve for the equilibrium price and the equilibrium utility in the case of pure specialization as a function of parameters. It has been shown that this utility is increasing in $\tau_{i1} \, and \, \tau_{i2}$ [see Abdel-Rahman (1996)]. In other words, *higher transportation costs lead to lower equilibrium utility*. Thus, there exist different combinations of $\tau_{i1} \, and \, \tau_{i2}$ that can sustain a given equilibrium utility. This is because since higher transportation costs imply that fewer resources will be used for consumption goods. In a pure diversified equilibrium configuration all cities in the economy will produce both final goods and both groups of intermediate goods. Given that the equilibrium utility level, V^*_d, is independent of $\tau_{i1} \, and \, \tau_{i2}$ since no trade will occur in a diversified system. Thus, we can conclude the following

Proposition 12. *There exists a set of values* $\{\tau_{i1}, \tau_{i2}\}$ *that would result in pure specialization system of cities and a set of values* $\{\tau_{i1}, \tau_{i2}\}$ *that would result in pure diversified system of cities.*

The intuition behind this result is that a specialized system will be the equilibrium outcome if the benefit from economies of scale, i. e., product differentiation, dominates the loss due to transportation cost. On the other hand, the system will be diversified if the reverse is true. This result can be tested empirically by comparing the industrial composition of cities in developed countries that possess developed inter-city transportation systems with that of cities in developing countries. An alternative approach in testing the result is to compare cities' industrial composition over time in a given country.[33]

Alex (2003) extended Henderson and Abdel-Rahman by introducing positive transportation cost into the model. He assumed iceberg transportation costs so that the utility is given by

$$u = \left[n q_i^{\sigma} + (m-1) n q_{-i}^{\sigma} \right] \quad (49)$$

where q_i is the quantity of each variety produced in the city where the consumer reside and q_{-i} is the quantity of each variety produced in other cities. Given this, we can derive the indirect utility as

$$V = \sigma c^{-1} \{ N + (\overline{N} - N) \tau^{\sigma / 1-\sigma} \}^{1-\sigma / \sigma} [1 - \mu N^{1/2}]^{1+\frac{(1-\sigma)}{\sigma}} \quad (50)$$

From the above equation we can conclude as follows

Proposition 13. The utility is increasing in the aggregate population as long as transportation cost is finite.

The above model would result in either a system identical cities each of which produce the same variety with not trade as in Abdel-Rahman (1988) if $\tau = 1$ or a system of company towns like in Henderson and Abdel-Rahman (1991) if $\tau = 0$.

Economy of scope

[33] See Anas and Xiong (2003) for the same model but with traded intermediate services as well as the final good at

Abdel-Rahman and Fujita (1993) introduced the first model that can explain the coexistence of a diversified and specialized city based on the concept of economies of scope [Panzar and Willig (1986)].[34] In this framework the reason for the formation of a diversified city is the benefit of joint production. These benefits are cost savings resulting from the existence of economies of scope, in which the total cost of producing more than one good jointly in one firm/city is less than that of producing them separately. On the other hand, the reason for the formation of specialized cities is due to scale economies at the firm level resulting from the existence of fixed cost in production. Unlike the models presented in the previous section, cities are formed here by surplus maximizing developers. The model generates three equilibrium configurations: (1) pure specialization, in which each city specializes in the production of one traded good; (2) pure diversification, in which all cities in the economy produce two goods; (3) mixed system, in which specialized and diversified cities coexist in the economy. The total labor requirement $L(X_1, X_2)$ for the production of output X_1 and X_2 in a given city is given as

$$\begin{array}{ll} F_1 + X_1^2 & if X_1 > 0 and X_2 = 0 \\ F_2 + X_2^2 & if X_2 > 0 and X_1 = 0 \\ F_d + X_1^2 + X_2^2 & if X_1 > 0 and X_2 > 0 \end{array} \qquad (51)$$

where F represents fixed labor requirements. Hence the average labor requirement is U-shaped, which represents the reason for the formation of a city. Thus, given the national utility level U and a price vector **P**, the developer must choose the optimal consumption bundle (x_1, x_2) per household by solving the following cost minimization problem:

$$\min_{x_1, x_2} = \sum_{i=1}^{2} P_i x_i , s.t. x_1^{\alpha_1} x_2^{\alpha_2} = U \qquad (52)$$

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positive transportation costs.

[34] See also Goldstein and Gronberg (1984) for a discussion of economies of scope in an urban context.

From the above problem we derive the total consumption cost for a city having population N such that each household achieves the national utility level U as

$$TCC(U,N) = A^{-1} P_1^{\alpha_1} P_2^{\alpha_2} UN \qquad (53)$$

Therefore, the surplus, S, from the development of a specialized city of type i, where i=x, z is given by

$$S_i = P_i (N - 2\mu N^{3/2} - F_i)^{1/2} - A^{-1} P_1^{\alpha_1} P_2^{\alpha_2} UN \qquad i = 1,2 \, (54)$$

where the first term on the LHS of (54) represents the total revenue form production, which is obtained from (51), (7), and the full employment condition in each city. The surplus from the development of a diversified city is given by

$$S_d = [P_1^2 + P_2^2]^{1/2} (N - 2\mu N^{3/2} - F_d)^{1/2} - A^{-1} P_1^{\alpha_2} P_2^{\alpha_2} UN \; (55)$$

The developer's problem is to maximize the surplus from the city development by choosing the city size. Given the above behavior, we can conclude as follows:

Proposition 14.*There exists a set of parameters* $\{F_1, F_2, F_d\}$ *such that:*

i) there exist a unique equilibrium pure specialized city system.

ii) there exists a unique pure diversified city system.

iii) there exist a unique mixed city system.

Pure Specialization, S, where each city specializes in the production of one good; this equilibrium configuration exists if the fixed costs of the specialized cities, F_i are relatively small compared to the fixed cost of the diversified city $F_{d.}$ Conversely, in order to have a pure diversification, fixed cost F_d must be relatively small compared to F_i. In other words, production in diversified cities has strong economies of scope. Thus, diversified cities are more economical to form that specialized cities. Finally, in order to have equilibrium configurations of mixed-x type [mixed-2 type], fixed cost F_1 [F_2] must be relatively small compared with F_d while F_d must be relatively small compared with F_2 [F_1].

Proposition 15. W*henever a specialized city and a diversified city coexist in an economy, the diversified city is larger than the specialized city.*

Although the above model generates a mixed system of cities, all cities in the economy are company towns. But company towns are not the most observed urban settlement. However, Abdel-Rahman (2000) introduced a model that generates company towns [Dixit (1973)] or a multi-firm cities [Henderson (1973)] based on the parameter of the model. The model is of a specialized system of cities in a closed economy producing one final good. The good is produced with the following cost function $C(X,G) = wX^2 + F(G)$, where G is the public infrastructure (such as water, electrical, sewer system, and training facilities) and where F is a fixed set up cost. It is assumed that F is decreasing function of G. Profit maximizing developers form cities in the economy, as discussed in section 3.3. A developer can form a company town or a multi-firm city. The developer can produce good X by a single firm with fixed setup cost in a company town or he can produce it by many firms in a city. If developer invests in public infrastructure, this will reduce the fixed set up cost for each firm in the city. This fixed cost reduction represents an agglomeration force that may result in the formation of a multi-firm city. As a result of this specification, one can have a system of identical company town or a system of identical multi-firm cities based on whether the developer will fined it profitable to invest in public infrastructure or not. The type of system that will emerge will depends on the impact of the investment on public infrastructure on the reduction of the fixed set-up cost for each firm. This idea can be used for joint production if the public infrastructure is used by two industries. In this case the joint use of public infrastructure can result in the formation of a diversified city. Thus we can generate the same equilibrium configuration but in which each city in the system is a multi-firm city.

Another extension of Abdel-Rahman and Fujita in the direction of multi-firm cities is Abdel-Rahman (1994). He extended the above model in two respects: first, by introducing a market for intermediate goods (services) which leads to a multi firm city; second, by examining the impacts of economies of scope due to lower variable costs resulting from interaction and coordination between two production processes. As a result, it has been shown that *if the economies of scope are in the form of lower fixed costs* [Abdel-Rahman and Fujita (1993)]*, the only possible equilibrium configurations are pure specialization and pure diversification* [unlike Abdel-Rahman and Fujita (1993)]. *However, if economies of scope are in the form of lower variable costs, mixed systems are also possible.* Therefore, the model generates different equilibrium parameter spaces depending on the form of the economies of scope, i.e., whether and to what degree economies of scope affect fixed or variable costs.

The model was also extended by Tsukahara (1995) to explain the joint provision of an essential public good such as police and fire protection, and optional public good, such as museums or stadiums. It was assumed that the costs of providing public goods are only fixed costs. In this context, *it was shown that if the fixed cost required for the provision of the essential public good is large, this results in a large city size. Therefore, the per capita cost of providing the optional public good would be low and joint provision leads to higher utility.* On the other hand, if the cost of providing the essential public good were small, this would result in small city size. Therefore, the per capita cost of providing the optional public good would be high and joint provision will not be the equilibrium outcome.

Product cycle

Most recently specialization and diversification has been analyzed in a dynamic model that resulted in system of cities in which diversified and specialized cities co-exist. Duranton and Puga (2001) developed the first model of product cycle in the systems of cities literature. In this model a metropoly play the role of a nursery for new products. They employed a model of product development where firm experiment with prototype in a diversified city until they find the ideal production process. After the firm identifies the ideal production process the firm move to specialized city to start mass production. Henderson, Kuncoro and Turner (1995) provided empirical support for this product cycle model in a system of cities. The main result of the paper is to identify the conditions that result in a unique steady stat in which specialized and diversified cities coexist. However, the size of the diversified city is the same as that of the specialized one, which is not consistent with the empirical observation nor with other theoretical model that result in the co-existence of diversified and specialized cities.[35]

7. *Heterogeneous Household and Income disparities*

Models with heterogeneous types of workers enable us to analyze the factors that determine skill distribution and income inequality and their impacts on welfare. These issues are becoming more important given the rise in income disparities nationally during the post World Ware II period. . This rise has been materialized in a dramatic decrease in the real wage of low-skilled labor as well as an increase in the wage of highly skilled labor. [36] Furthermore, large cities tend to be populated with a labor force characterized by a wide variety of skills while small cities tend to be populated by a labor force with relatively specific skills. As a result income disparity is relatively large in large cities compared to small and medium sized cities. Thus, there is a need for models that examine, in a theoretical framework, the relationship between skill distribution and income disparity between cities

[35] For models in which diversified and specialized cities co-exist see Abdel-Rahman and Fujita (1990) and Abdel-Rahman (1994).
[36]See Juhn, Murphy and Pierce (1993) for these trends in the U.S. and Machin (1996) for the U.K among others.

within a hierarchical structure as well as within different types of cities. This section is devoted to survey of the initial work in this direction. Two types of models are reviewed; the first type of model analyze the case of exogenous types of households /workers, while the second type of model analyze the case where the types of households/worker is determined endogenously through a self-selection mechanism. The first group of models can be further classified into models that result into the same equilibrium wage and utility level for households with different skill characteristic [like Kim (1991) and Helsley and Strange (1991)] and model that result into different equilibrium wage and utility level for households with different skill [like Becker and Henderson (2000), Abdel-Rahman and Wang (1996) and (1997)].[37]

Becker and Henderson (1998) introduced a model of intra-industry specialization that resulted in a system of identical cities. The economy is populated with two types of households, workers and entrepreneurs. The mass of entrepreneurs is $a\overline{N}$ where $a > 0$ representing the ratio of entrepreneurs to workers. The entrepreneurs allocate one unit of time between different tasks, s, (on a unit circle) to manage n_w workers in performing each task. The output of a given firm operated by an entrepreneur is given by

$$x(s) = I(s)^{\beta} n_w(s)^{\gamma} \qquad \beta + \gamma > 1 \qquad (54)$$

where I(s) is time devoted to each task. Given a segment of width D on the unit circle, then ID=1. If there is m firm in the city in a symmetric equilibrium and the output of the city require all tasks to be performed, firm will choose equal widths D and thus $Dn_I = 1$. The industry

[37] Henderson and Thisse (2001) in a non-spatial model examined the distribution of households differentiated by income between communities where community developers provide public good and behave strategically. In that model the income distribution is given exogenously and public good is differentiated by quality.

output in the city will be $X = n_I^{\beta} n_w^{\delta}$. Cities are formed by profit maximizing developer. The objective function of the developer is

$$\max \pi_{n_I, n_w} = n_I^{\beta} n_w^{\gamma} - U_w n_w - U_I n_I - 2\mu(n_w + n_I)^{3/2} \quad (55)$$

The first order conditions for the above problem are

$$U_I = \beta X n_I^{-1} - 3\mu(n_w + n_I)^{1/2} \quad (56)$$

$$U_w = \gamma X n_w^{-1} - 3\mu(n + m)^{1/2} \quad (57)$$

Given that the economy is sufficiently large so that developers make zero profit in equilibrium and given full employment, we have the equilibrium city size as

$$N = \left\{ \left[(\beta + \gamma - 1) 2\mu^{-1} (1+a)^{-3/2} a^{\beta} \right]^{1/(.5-\beta-\gamma)} \right\} (1+a) \quad (58)$$

Proposition 16. *The equilibrium city size increase with the degree of economy of scale,* $(\beta + \delta)$, *and decrease with commuting cost.*

Observe that, as $(\beta + \delta) \to 1$ cities will not form in this economy since there is no economy of scale in production.

Abdel-Rahman (1998) presented another approach in modeling income inequalities and analyzing its impacts on social welfare. The model is of a two-sector economy consisting of two types of cities where the number of cities of each type is determined endogenously. Cities are formed as a result of investment in public infrastructures. This investment leads to a reduction in commuting cost and consequently to an increase in the time that households can utilize for work and leisure. In the context of the model the level of investment in public infrastructures is chosen optimally. Skilled labor locates in one type of city while the unskilled labor locates in the other type. Wages in both labor markets are determined competitively. This model explains the variation in city sizes as a result of differences in households' value of time.

Abdel-Rahman and Wang (1997) considered an economy populated by a continuum of unskilled workers of mass $\overline{N_U}$ and skilled workers of mass $\overline{N_S}$.[38] The economy produces two homogeneous goods X_i i=1,2. Skilled or unskilled workers produce good X_1 with CRS production function as in section 3, but skilled workers can only produce good X_2. Unskilled workers are homogeneous. On the other hand, skilled workers are heterogeneous in their skill characteristics. Their type, Y, can be thought of as uniformly distributed on a circle with unit circumference such that $N(Y) = \overline{N_S} \forall Y \in [0,1]$. The mass of skilled workers can be written as $N = \int_0^1 N(Y)dY = \overline{N_S}$. The wage for the unskilled workers, W_U, is determined competitively, whereas the wage for skilled workers, W_S, is determined via a bargain Nash outcome with the high-tech firms. Each individual firm of type $R \in [0,1]$ in the high-tech industry has a different skill requirement. In particular, it would be ideal for a firm of type R to employ a worker of skill type $R = Y$ since a perfect match generates maximal output per worker, O. Skill matching is generally imperfect: a high-tech firm of type R may need to employ skilled workers of type Y with distance $\delta = |Y - R|$ away from the ideal skill mach. In this case, the corresponding productivity is given by $O - C\delta$, where C measures the productivity loss from a mismatch. Let D denote the maximal distance of skill miss match, which will be endogenously determined in a Nash outcome. We can now specify the output of a high-tech firm of type R

[38] This model is an extension of Helsley and Strange (1991) and Kim (1991) where they considered only heterogeneous skilled labor force. The basic deference between Helsley and Strange and Kim is that in the former, skilled worker and firms has incomplete information while in the later both skilled workers and firm have complete information about the job requirement and worker skill characteristic.

as $X_2(R) = 2\overline{N_S}\int_R^{D+R}(O - C\delta)d\delta - K = 2\overline{N_S}\int_0^D(O - C\delta)d\delta - K$ where K is the fixed entry cost. The second equality is a result of symmetry. Since each firm employs skilled workers over an interval of measure 2D, the total number of firms in the high-tech industry will be $M = 1/(2D)$. Under the symmetry assumption and with the use of equation (4.2), the profit of a type-S firm is given by $X_2(R) = 2\overline{N_S}\int_0^D[(O - C\delta) - W_M(\delta)]d\delta - K$.

Now consider a bargaining situation facing a skilled worker with a characteristic distance away from the most adjacent firm. To bargain with the most adjacent firm, a worker needs to take the best alternative into account. In principle, the best alternative could be the potential earning from employment by the second most adjacent firm in the X_2 sector. Given the wage rule that the surplus of the matched is divided equally between the firm and the worker, the wage for the skilled labor is given by $W(\delta) = O - CD$. From the zero profit condition we have $D = \left(\frac{K}{C\overline{\overline{N_S}}}\right)^{1/2}$ and thus the equilibrium wage is

$$W_S = O - \left(\frac{CK}{\overline{\overline{N_S}}}\right)^{1/2} \quad (56)$$

The above equation represents a micro-foundation for localization economy. Indeed any increase in the size of the labor force enhances matching in the labor market and increases productivity and the wage rate.

Proposition17. *The above model does not generate structurally the same indirect utility or city size as in Proposition 7.*

The formation of local cities and the metropolis in this economy require a public infrastructure (such as intercity transportation system) produced using the numeraire good. The total cost for this public infrastructure is shared by city residence. Thus, this represents the incentive for the agglomeration behavior in local cities. The total cost of public infrastructure required for the formation of local cities and the metropolis are FN_U^{ε} and FN_S^{ε} *where* $\varepsilon \in (0,1)$ *and* $F > 0$. Under the assumption that commuting costs is in terms of the numeraire good, the indirect utility is given by

$$V_U(N,P) = AP_1^{\alpha_1} P_2^{-\alpha_2}[1 - FN_U^{\varepsilon-1} - 2\mu N_U{}^{1/2}] \qquad (57)$$

$$V_S(N,P) = AP_1^{\alpha_1} P_2^{-\alpha_2}[O - \left(\frac{CK}{\overline{N_S}}\right)^{1/2} - F\overline{N_S}^{\varepsilon-1} - 2\mu \overline{N_S}^{1/2}] \qquad (58)$$

Proposition18. *Under some regularity condition, there exists a core-periphery system of cities in which the economy would have a single metropolis, populated by skilled workers, and a number of local cities, populated by unskilled workers.*[39]

Now let us examine the income inequality measure that has been used to measure the earned income difference between the core and the periphery region given by $W_S - W_U$. It has been shown that, *the inter-regional income inequality is increasing in the commuting costs, t, or city formation cost, F, as well as in the mass of unskilled workers,* $\overline{N_U}$ *, and the level of productivity of skilled workers, O. Furthermore it is decreasing in the entry cost, K, and the mismatch, C.* Thus, the main determinants of geographical income inequalities include: (i) traditional economic factors, such as labor productivity and the mass of unskilled labor; (ii) spatial factors,

[39] The above result is unlike Helsley and Strange (1991) where they generated a system of identical cities where each city is populated with a continuum of skilled workers with differentiated skill.

consisting of the costs to commute to and from the CBD; and (iii) search and matching factors, such as entry and mismatch costs, relative bargaining power, and mass of skilled workers.

To examine the impact of income inequality on the social welfare Abdel-Rahman and Wang (1996) used a social welfare function that uniformly aggregated all households' utilities achieved in equilibrium. They showed that *reduction in the cost of entry or mismatch or increase in the bargaining power or mass of skilled workers reduces within the core income inequality and enhanced social welfare. Also a decrease in the cost of commuting or city formation reduces the interregional income inequality and increases social welfare. Furthermore, a lower level of maximal productivity of the skilled workers or smaller mass of unskilled workers decreases the interregional income inequality, but it reduces social welfare.* Therefore, public policies designed to reverse the observed urbanization trend of widening geographical income inequality may not necessarily improve welfare.

One important assumption in the model is that selective migration is not allowed. In other words, a matched high-tech firm and skilled workers cannot form a new city. This assumption resulted in single metropoly. However, violation of this assumption would result in a system of company town as in which each company town would have a single firm and it would be populated with the workers that best mach the firm skill requirement. The reason for that is that there would be no benefit of having more than one firm locates in the same city a result of that a growth of the population of skilled worker in the economy would lead to higher productivity. Since in this case the population growth lead to a better mach between firms and workers leaden to more specialization and higher utility in the economy. Thus, we conjecture that this model can result in national economy of scope as in Henderson and Abel-Rahman (1991).

Abdel-Rahman (2002) extended the previous models with endogenous types of workers to a model that generates the skill distribution endogenously within the system of cities as well as different structures of city systems. Workers in this economy are identical in terms of productivity and each is endowed with one unit of time. However, they are heterogeneous in their potential ability. Potential ability can be materialized as productivity if workers acquire specialized training and produce x with the use of specialized technology. Workers with potential ability δ are uniformly distributed on a unit interval such that $\overline{N}(\delta) = \overline{N} \quad \forall \delta \in [0,1]$. The potential ability of a worker $\delta \quad \forall \delta \in [0,1]$, is given by $\Omega = O(n_s, T) + C\delta$, where C is positive constant. Thus, the potential ability of worker type $\delta = 0$ is zero while the potential ability of worker type $\delta = 1$ is O. If a worker of type acquires specialized training and reside in a high-tech city, then the production function for a worker of type δ will be translated into productivity given by $\Omega = O(n_s, T) + C\delta$, where O(.,.) is an externality function to capture human capital accumulation and information spillover. It is assumed that O is an increasing function of the amount of labor with specialized training in a given city, N_s. Furthermore, it is assumed that O is increasing in the level of specialized training provided in a given city, T. It has been shown that higher productivity is associated with additional years of education.[40] In this framework, the most productive type of worker is a worker of type =1. This worker utilizes the specialized technology and is the one with the highest potential ability that matches to this technology, i.e., workers of type =1. This can be interpreted as if firms in industry X_1 have job requirements which perfectly match the potential ability and the specialized training acquired by worker type =1. On the other hand, workers with potential ability =0 have the poorest match with the

[40] For example Rauch (1993) found that a year increase in the average level of education in a metropolitan area raises total factor productivity by 2.8%.

specialized technology. Now, the mass of workers can be written as $\overline{N} = \int_0^1 \overline{N}(\delta)d\delta$ where $\overline{N}(\delta) = \overline{N} \forall \delta \in [0,1]$. Workers in a given city can acquire specialized training by paying a training cost. The total cost of specialized training in a given city is $TC(T) = \tau T^{\theta}\ wher\quad \tau, \theta > 0$. Thus, the average training cost in a given city is decreasing in city size, this represents one reason for the formation of a high-tech city. In other words, the (per capita) cost share represents the second agglomeration force and that results in city formation. Workers utilizing the specialized training will concentrate in the city to get the advantage of lower per capita cost share. Semiskilled labor, N_U, can also produce good X_1 if they acquire basic training and use general technology, Furthermore, it is assumed that productivity is an increasing function in the level of basic training in a given city, G. This represents one agglomeration force that results in city formation. Given the above specification, the production function of good X_1 is given as $X_1 = BG^{\beta}\delta_U$, where δ_U .is the measure of semiskilled workers to be determined below, and G is the level of basic training. The total cost of basic training is given by, $TC(G) = bG^{\varphi}\ wher\quad b, \varphi > 0$. Thus, the (per capita) cost share of basic training decreases with city size. This benefit, i.e., cost sharing; represent the second agglomeration force that results in city formation.

It is assumed that good X_1 is the numeraire, thus its price is normalized to be one. Given this assumption, production efficiency implies that skilled workers of type δ. are paid their marginal product given by $W_S(\delta) = N_s^{\gamma} T^{\theta} + O\delta$. It is clear that the wage income for the skilled worker increases in the level of training and the amount of trained labor in the city due to information spillovers. Thus, an individual's investment in his skill creates external benefits to other skilled labor in the city. In addition, the wage for semiskilled labor is given by $W_U = BG^{\beta}$. The equilibrium city system is characterized by the following set of conditions hold

$$Max_{n_u,G} V(n_{u,} G)$$

$$Max_{n_u,T} V(\delta, n_s, T) \delta \in [0,1] \qquad (58)$$

$$V_u = V_s(\delta) \delta \in [o,1]$$

$$\sum_{i=u,s} m_i n_i = M$$

Condition (1) means that the local government of the low-tech cities forms the city by choosing the city size and the level of basic training that maximizes the utility of semiskilled workers. Condition (2) means that the city government chooses the city size and the level of specialized training that maximizes the utility of the skilled workers. Condition (3) means that the marginal worker who will be indifferent about acquiring specialized training or basic training determines the measure of semiskilled workers in the economy. Finally, condition (4) means that all households in the economy reside in the existing cities.

In order to solve for the equilibrium system of cities, first we have to derive the indirect utility for a representative household of a given type as a function of city size and level of training.

$$Max_{G,n_u} V(G, N_u) = BG^{\beta} - 2\mu N_u^{1/2} - bG^{\varphi} N_u^{-1} \qquad (59)$$

Now we turn to the formation of high-tech cities, we can derive the utility of a representative skilled worker in a given city as

$$Max_{T,n_s} V(\delta, T, N_s) = N_s^{\gamma} T^{\gamma} + \alpha\delta - 2\mu N_s^{1/2} - \tau T^{\theta} N_s^{-1} \qquad (60)$$

Observe, also in this case, that *the equilibrium level of training*, the *equilibrium city size, and the equilibrium provision of specialized training are efficient.* This is because the local government internalized the externality resulting from the level of specialized training as well as the externality resulting from increasing the number of skilled workers in the city. Observe that the model results in a continuum of equilibrium utility levels.

The marginal worker who will be indifferent about acquiring specialized training or basic training determines the measure of semiskilled labor in the economy. In this context, a worker with potential ability δ_U will be indifferent about acquiring specialized training or not. Thus, the utility of a semiskilled worker (26) and the utility of a skilled worker (31) will be equalized for a worker with potential ability δ_U^*.

Proposition19. *There exists a set of parameters such that* $\delta_U{}^* \in (0,1)$*, where some workers will acquire specialized training and some will acquire basic training.*

This is the most observed outcome since under this condition, the model will generate two types of cities: high-tech cities populated by skilled workers and some low-tech cities populated with semiskilled workers. Under this equilibrium configuration, the number of high-tech cities as well as the number of low-tech cities is determined by the parameters of the model. Furthermore, the resulting city system could be a single large high-tech metropolis (core) and a system of small local cities (periphery) as in Abdel-Rahman and Wang (1995). However, unlike in Abdel-Rahman and Wang, the system of cities and the distribution of skill are the outcome of the model and not imposed exogenously.

The main determinants of geographical income disparities include: *(i) traditional economic factors* such as labor productivity, basic education, and training costs, *(ii) spatial factors* such as commuting costs. It can be seen that as the number of high-tech cities in the economy decreases, income disparities will increase. *In other words, the model predicts that economies that are dominated by a large metropolis and a large number of small low-tech cities would have high-income disparities.* This result ties income disparities to the structure of an urban system.

Then a social welfare function by uniformly aggregating all households' utilities.

$$\omega = \int_{0}^{\delta_U} N_U V(G, N_U) d\delta + \int_{\delta_U}^{1} N_S V(T, \delta, N_S) d\delta \quad (61)$$

where V_u (.)and V_s(.) are given by (59) and (60). The first term in the above equation is the total utility of semiskilled workers, while the second term is the total utility of the skilled workers.

The equilibrium system of cities in the economy is efficient.

Propositio20.

(a) An increase in C increases income disparity and increases social welfare.

(b) An increase in τ decreases income disparity and social welfare.

(c) An increase in b or t increases income disparity but decreases social welfare.

(d) An increase in B deceases income disparity but increases social welfare.

8. Efficient system of cities

The concept that we will adopt in this section is the Pareto efficiency of resource allocation in a closed economy where the member of cities is endogenous. In the process of calculating the efficient allocation we assume the economy is sufficiently large so that we have a large number of each type city within the economy.[41] This is to be consistent with the equilibrium that we discussed in section 4. Our objective is to address three fundamental questions concerning

[41] This assumption is imposed so that we can ignore the lumpiness problem, Henderson (1985) chapter 11, and page 240-242.

efficiency: 1) what is the source of inefficiency or market failure in the model? 2) Does the first best require national ore only local government intervention? 3) What are the instruments, tax/subsidy or both, that has to be used to achieve efficiency

Lest consider the case in which the only reason for city formation in the economy is the provision of public good as in section 4.1. Suppose that the economy is populated with $\overline{N}$ identical households each is endowed with one unit of labor. The objective of a centrally planning authority is to maximize a social welfare function defined as the aggregate utility of all households in the economy. This problem is equivalent to maximizing the utility of a representative household given that all cities are identical. This is maximized subject to two types of constraints: the first is technology constraints given in section 4.1. The second type of constraint is the resource constraint $N - kN^{3/2} = L_2 + L_1$. The problem of the central planning authority is obtained by substituting the constraints into the utility function we have

$$\max_{L_1, Z, N} u = \eta^{\alpha_2} N^{-1} (L_1 - Z))^{\alpha_1} \left(N - 2\mu N^{3/2} - Z\right) Z^{\alpha} \quad (62)$$

The first order conditions after rearranging terms are

$$\frac{\partial u}{\partial L_1} = -\frac{\alpha_2}{\left[N - 2\mu N^{1/2} - L_1\right]} + \frac{\alpha_1}{L_1 - Z} = 0 \quad (63)$$

$$\frac{\partial u}{\partial Z} = \frac{\alpha_2}{Z} - \frac{\alpha_1}{L_1 - Z} = 0 \quad (64)$$

$$\frac{\partial u}{\partial N} = -\frac{\alpha_2 (1 - 3\mu N^{1/2})}{\left[N - 2\mu N^{1/2} - L_1\right]} + \frac{1}{N} = 0 \quad (65)$$

Condition (63) requires that the marginal cost of a worker to industry X_1 be equal to the marginal benefit. Condition (64) is the Samuelson condition for the optimal provision of public good. Condition (65) require the equality of the marginal benefit of a household to the city, i.e., the reduction in per capita cost of public good, given by the first term, and the marginal cost, i.e., the rise in land rent, given by the second term. If we multiply through by N we get that the aggregate land rent is equal to the cost of provision of public good, which is the Henry George condition. Observe that the fist best optimal result is consistent with the decentralized equilibrium presented in section 4.1.

Proposition 21. *To achieve the social optimal city system the developer of each city to tax the aggregate land rent to finance the provision of public good in each city.*

Now let us consider the case of a system of cities with externality in production. Suppose that all households in the economy have identical utility function given by (1). Both X_i are produced with external economy of scale $X_i = L_i^{1+\varepsilon_i}$ $i = 1,2$. Thus, this economy will result in a system of specialized cities. One type of city will specialize in the production of good X_1 while the other will specialize in the production of good X_2. The objective of a centrally planning authority is to maximize the utility of a representative household given equal utility of household living in city type 1 and city type 2. This is maximized subject to two technologies and the full employment constraints $N_i - kN_i^{3/2} = L_i \quad i = 1,2$ and the population constraint for the economy $\overline{N} = \sum_i M_i N_i$, where M is the number of cities. Thus, problem of the central planning authority is given by

$$\max_{x_{11}, x_{12}, x_{21}, x_{22}, N_1, N_2, M_1, M_2, u} u \quad (65)$$

$$\text{S.t. } \lambda_i : \quad u = x_{1i}^{\alpha_1} x_{2i}^{\alpha_2} \qquad i = 1,2$$

$$\gamma_i : \quad M_i (N_i - 2\mu N_i^{3/2})^{1+\varepsilon_i} = x_{i1} M_i N_1 + x_{i2} M_2 N_2 \qquad i = 1,2$$

The first order conditions after rearranging terms are

$$\frac{\partial L}{\partial x_{1i}} = \frac{\alpha_1 \lambda_i u}{x_{1i}} - \gamma_1 M_i N_i = 0 \qquad i = 1,2\ (66)$$

$$\frac{\partial L}{\partial x_{2i}} = \frac{\alpha_2 \lambda_i u}{x_{2i}} - \gamma_2 M_i N_i = 0 \qquad i = 1,2\ (67)$$

$$\frac{\partial L}{\partial N_i} = \gamma_i \left[(1+\varepsilon_i)\left(1-3\mu N_i^{1/2}\right)\left(N_i - 2\mu N_i^{3/2}\right)^{\varepsilon_i} - x_{1i} M_i\right] - \gamma_2 x_{21} M_i = 0 \qquad i = 1,2\ (68)$$

$$\frac{\partial L}{\partial n_i} = \gamma_i \left[\left(N_i - 2\mu N_i^{3/2}\right)^{1+\varepsilon_i} - x_{1i} N_i\right] - \gamma_2 x_{21} N_i = 0 \qquad i = 1,2\ (69)$$

$$\frac{\partial L}{\partial u} = 1 - \lambda_1 - \lambda_2 = 0\ (70)$$

The interpretation of the Lagrange multipliers are λ_i representing weights attached to different households to obtain equal utility and γ_i are shadow prices of good 1 and 2. The first two conditions require the equality between the marginal rate of substitution and the relative shadow prices. The third condition require the equality of the marginal benefit of a household to the city, i.e., the external economy of scale, given by the first term, and the marginal cost, i.e., the rise in land rent, given by the second term. If we multiply through by N we get that the aggregate land rent is equal to the cost of provision of public good, which is the Henry George condition. The forth condition equate the cost of adding one city of type i, given by the consumption costs by, to it benefit, the value of output. Solving the first order conditions we have

$$N^*_i = \left[\left(\frac{\varepsilon_i}{1+3\varepsilon_i}\right)\mu^{-1}\right]^2 \qquad i = 1,2\ (71)$$

$$M^*_i = \alpha_i \overline{N}\left[\left(\frac{1+3\varepsilon_i}{\varepsilon_i}\right)\mu\right]^2 \qquad i = 1,2\ (72)$$

Proposition 22. *The fist best optimal solution is consistent with the decentralized equilibrium presented in section 4.2.*

Thus, all what we need to achieve the social optimal city system is for the developer of each city to tax the aggregate land rent and use it to finance a lump-sum subsidy to workers in the city that will be the deference between the privet marginal product of worker and the social marginal product. Two observations about the first best optimal; the first is the city size is only dependent on the parameters for commuting costs and the parameter for the scale economy. The second observation is that the demand parameters do not affect the city size but affect the number of cities of each type in the system. Finally an increase in the population of the economy will leave the relative number of cities unaffected. In other word, the city size distribution remains the same.

Turning now the social optimal of differentiated intermediate inputs. Suppose that households have the same utility function as in section 4.3 above. But x_1 and x_2 are produced with two groups of differentiated inputs. The final good are traded between cities at zero transportation costs while the differentiated inputs are not traded. Furthermore suppose that each of the differentiated input is produced by $L_{ij} = c_i q_{ij} + f_{ij} \; i = 1,2 \quad j = 1,\ldots,n$. It is assumed that differentiated input is not traded but final good are traded between cities at zero transportation costs. In a symmetric case and given equal utility of households in different type of cities, the central planning authority's problem is

$$\max_{x_{11},x_{12},x_{21},x_{22},N_1,N_2,n_1,n_2,u} u \quad (73)$$

$$\text{S.t. } \lambda_i : \quad u = x_{1i}^{\alpha_1} x_{2i}^{\alpha_2} \qquad i = 1,2$$

$$\gamma_i : \quad M_i n_i^{\frac{1-\beta_i}{\rho_i}} L_i^{\beta_i} q_i^{1-\beta_i} = x_{i1} M_i N_1 + x_{i2} M_2 N_2 \qquad i = 1,2$$

$$\delta_i : \quad n_i(f_i - c_i q_i) + L_i = N_i - 2\mu N^{3/2}{}_i \qquad i = 1,2$$

The first order conditions after rearranging terms are

$$\frac{\partial L}{\partial x_{1i}} = \frac{\alpha_1 \lambda_i u}{x_{1i}} - \gamma_1 M_i N_i = 0 \qquad i = 1,2\,(74)$$

$$\frac{\partial L}{\partial x_{2i}} = \frac{\alpha_2 \lambda_i u}{x_{2i}} - \gamma_2 M_i N_i = 0 \qquad i = 1,2\,(75)$$

$$\frac{\partial L}{\partial q_i} = \gamma_i \left[\frac{(1-\beta_i) X_i M_i}{q_i} \right] - \delta_i c_i n_i = 0 \qquad i = 1,2\,(76)$$

$$\frac{\partial L}{\partial L_i} = \gamma_i \left[\frac{\beta_i X_i M_i}{L_i} \right] - \delta_i = 0 \qquad i = 1,2\,(77)$$

$$\frac{\partial L}{\partial N_i} = \gamma_i \left[\left(1 - 3\mu N_i^{1/2}\right) - x_{1i} M_i \right] - \gamma_2 x_{21} M_i = 0 \qquad i = 1,2\,(78)$$

$$\frac{\partial L}{\partial M_i} = \gamma_i \left[X_i - x_{1i} N_i \right] - \gamma_2 x_{21} N_i = 0 \qquad i = 1,2\,(79)$$

$$\frac{\partial L}{\partial u} = 1 - \lambda_1 - \lambda_2 = 0\,(80)$$

The interpretation of the first and the second condition is as in the previous case. The third condition require the equality of the marginal benefit of an additional differentiated input to the city, given by the second term, and the marginal cost, i.e., the rise in fixed cost, given by the first term. Solving the first order conditions we have

$$n^*{}_i = \left[\frac{1}{f_i \mu^2} \left(\frac{(1-\rho_i)(1-\beta_i)}{\left[\rho_i + 3(1-\rho_i)(1-\beta_i)\right]} \right)^3 \right] \qquad i = x, y\,(81)$$

Proposition 23. *The equilibrium, given in section 4.3, is not fist best optima.*

First, observe as in the previous case that the city size is independent of the demand parameters. Second, the number of cities of each type is the same as in the previous model.

Third, Observe that the fist best optimal result is not the same the decentralized equilibrium presented in section 4. However, if local government regulate the price of the intermediate input to the marginal cost and offer lump-sum subsidy given to the suppliers of the differentiated input equilibrium city size and the equilibrium number of firms will be a first best optima. Furthermore, the subsidy can be financed by the aggregate land rent generated in the city. Thus, all what we need to achieve the social optimal city system is for the local government of each city to tax the aggregate land rent to finance the fixed cost in each city. A similar model that would lead to the same result is the model of differentiated product that is consumed by household, Dixit and Stiglitz (1974).[42]

Now let us consider the case of national economy of scope arising from product diversity in the production of consumption good. This argument support that large countries can support a grater range of differentiated product, which improve the utility of household in the nation. In this framework national diversity involve diversity in the type of cities and in the traded good in which the city specialize. Consider now the case in which the differentiated good is traded at zero transport cost and those households have the utility function $u = n^{1/\sigma} q$. In this framework each city in the economy specialize in the production of one q. Thus, the number of cities in the economy is the same as the number of variety. The planner problem is

$$\max_{N} u = \left\{ c^{-1} \overline{N}^{\frac{1}{\sigma}} n^{\frac{1}{\sigma}} \left(N - 2\mu N^{3/2} - f \right) \right\} (82)$$

The first order condition for the above problem after rearranging terms is

$$\frac{\partial L}{\partial N} = \left(N - 3\mu N^{3/2} \right) - \tfrac{1}{\sigma} \left(N - 2\mu N^{3/2} - f \right) = 0 \, (83)$$

[42] See Hobson (1987) and Abdel-Rahman (1988) for this result.

This first order condition determine the city size as

$$\left(N-\left[\frac{2-3\sigma}{1-\sigma}\right]\mu N^{3/2}\right)=f(1-\sigma)^{-1}(84)$$

The above city size equation would result in a larger size than equilibrium, which is given by $\left(N-2\mu N^{3/2}\right)=f(1-\sigma)^{-1}$. This equilibrium city size is determined by the full employment condition for a representative city given that cities will charge markup price, $P=\frac{c}{\sigma}$.

Proposition 24. *Equilibrium will underprovided the number of variety/cities in the economy.* Since this will be a system of company towns in this case a local developer can correct this market failure by maximizing the profit from production of the traded good and the tax collected from city residence. This has to be maximized subject to full employment in the city, national demand for the traded good produced in the city, and utility constant that indicate that the developer has to maintained the national utility level for city residence. Given this behavior of local developers the social optimal city size will be achieved. As can be seen in all of the above models that even though the equilibrium does not correspond to the social optimal, all what is required to correct this market failure is local government intervention, see Henderson and Abdel-Rahman (1991).[43]

This result of achieving first best with a decentralizing equilibrium is only true if the utility function does not have an outside good. However, if there is an outside good as in equation (35) social optimal cannot be achieved through a decentralization mechanism. Thus, in this case we need a central planner in order to reach a social optimal. This is also required in Anas and Xiong (2003), in which the intermediate differentiated input is traded

[43] Also see Anas (2003) for this model with positive transportation costs.

between cities, to specify the industrial mix in each city. The reason for that is city developer or local government cannot internalize the externalities associated with formation of new cities in the economy. Thus, in these cases we need national government intervention to internalize these externalities.

9. Conclusion

In spit of the major development in the theory of system of cities over the past two decades or so, there are still major challenges that lay ahead towed the formation of more complete theory. In most of the city systems that we discussed in this survey the system of cities generated is either specialized or diversified system. However, most system of cities that we observe in developed or developing countries have specialized and diversified system coexists. Thus, there is a need for more intensive research that would explain this phenomenon.

On the other hand, most observed city system is characterized by a dominant city, which is characterized by a divers industrial structure and a diverse labor force. In other words, there is a need for more work on the core periphery model that can explain a hierarchal structure of an urban system. Some attempts in this direction started like Abdel-Rahman and Wang (2000) and Abdel-Rahman (2002). However, there is a need for models that generate the core periphery structure endogenously.

Now with trade liberalization and free trade agreements the role of national government in infusing trade has been wakening an the role of cities competing internationally has been expanding. Thus, we need models that can explain the impact of free trade agreements on the structure of the system of cities. In other words we need models that can merge international trade theory with the theory of system of cities.

Finally, a technically challenging model is one that will integrate special dimension to NUE system of cities. This will integrate the NEG model, in which the distant between cities is taken into consideration, and NUE model, in which the internal special structure of the city is taken into consideration. The simplest approach of doing that is by considering a linear city model with explicit introduction to a ruler sector.

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