

Vertically linked industries and the monocentric city

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Abstract

In this paper we study how the relations between the industry and more and more specialized services firms can explain the rise of suburban industrial clusters. We build an urban economics model with two vertically linked sectors. The vertical disintegration liberates the location choice of the industry and the services. Then, the industry clusters that need more land may leave the center (what characterizes the modern city). When the industry is higherly linked to the services it agglomerates around the CBD (what characterizes the post-modern city).

Keywords: urban development, vertical linkages, spatial disintegration, suburbanization, firm location

JEL Classification: L23 - N90 - R12

1 Introduction

Now as opposed to the seventies, a metropolitan area is not just a big city. It's a miles long succession of Central Business Districts (CBD) and Industrial Clusters (IC). As J. Garreau (1991) writes it, more and more cities appear

^{*}I Greatly thank Hubert Jayet and Romain Lesur for their help and Pierre-Philippe Combes, Philippe Martin, Gianmarco Ottaviano and Jacques-François Thisse for helpfull comments on previous versions of this paper.

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on the edge of the million towns. This supposes not only that households have moved from the center toward suburban areas but also that important intra-urban movements of firms have occurred from downtown area to the garden areas. This change goes back to the early twentieth century. We build a model that catches how the evolutions of the vertical relations between industry and services lead from the industrial city, when the city is mostly industrial and is monocentric, to the modern city where the city is surrounded with IC and then to the post-modern city, where the industry tends to cluster around the specialized CBD.

Most of the literature on suburbanization considers that *jobs follow people* (Steinnes (1982)). Two strands of models are related to this explanation. On the one hand, some consider that consumers generate agglomeration because they prefer diversity. In Anas and Kim (1996) for example, the retailers have incentives to agglomerate, causing people to agglomerate in return and hence attracting firms in the suburbs. On the other hand, an increase in the population may increase both the size of the city and the transportation costs from the suburbs to the center. In both ways it makes it more profitable to locate the clusters closer to the suburban population as in Henderson (1988).

But there is also a second tradition which considers that *people follow jobs*. There has been only few models in urban economics explaining how suburbanization may be caused by the choices of the firms, and most of them are based on the idea of a market power. In a model à la Henderson and Mitra (1996), a developer chooses to organize a piece of land in order to attract firms. The basic idea is that if there are enough firms, there will be households and the developer will make profits: once the place hosts some firms, households locate around it and that creates an edge city. Here, the developer has a market power and uses it to attract firms and generate suburbanization. It's however possible to think about firm suburbanization without any land developer. Fujita, Thisse and Zenou (1997) have proved that if a firm has an influence on the labor market and knows it, the foreseen consequences of its choice may be important enough to decide the relocation and then create an edge city. We stand in this second tradition, since our model relies on the location choice of the firms. What is new is that we do not assume any kind of market power.

Actually, in parallel with the spread of multipolar cities, there has been a strong movement toward spatial disintegration of the production. We usually consider that a spatial disintegration is horizontal or vertical (Fujita and Thisse (1996)). It is horizontal if every unit of a multi-located firm host the

same activities. It is vertical if all these units are specialized in different productions, such as in Los Angeles. There, Scott (1987) notes that each sector tends to be clustered at a proper place. This is to be linked with the strategy of the firms. McLaren (1998) has shown that firms have less and less interests in being strongly vertically linked as globalization rises. For example, industrial firms externalize their strategy and managing to consulting groups. As far as urban structure is concerned, this has the same consequences as the development of multi-located firms: as the industrial disintegration occurs, Hansen (1990) explains that there is also a strong movement toward spatial disintegration. Whereas an integrated firm has to aggregate the needs of all its activities, the break of a vertical linkage allows each sector to choose the most adapted location. Now, Delisle and Lainé (1998) have observed that, in the French case, most of the firms relocates within a radius of fifteen miles, that is to say in the same urban area. Hence Consulting groups are usually clustered in the CBD and communicate with each other. Industrial firms are mostly located around the city; these firms do not interact with each other and they need land. The location of the factories of the automotive or the chemical industries in greater Paris as noted by Gilli (2001) tends to prove it. The vertical disintegration in the production may then lead to a vertical spatial disintegration. In the remainder, we focus on this and its consequences on the land use pattern.

Since the first papers by Fujita and Ogawa (1980,1982), most of the urban economists have wondered whether the monocentric assumption was sustainable or not considering an economy with only one sector (the agriculture is out of the city). A quite simple way (but technically complex to achieve) to think about spatial disintegration is to split the firm into two units, a front-unit and a back-unit. Ota and Fujita (1993) built such a model. But as they point it in their conclusion, they neglect the direct interactions of back-units with other firms and households and they would need more general utility and production functions. If we take the disintegration as both spatial and industrial, some of the problems referred to by Ota and Fujita could be solved. In our model, the back-unit potentially interacts with all the consulting groups and households: we do not use shadow-prices as Fujita and Ota did, and the production functions can be very general. We build a model à la Krugman and Venables (1995) with vertically linked industries in an urban economics way.

Abdel-Rahman and Fujita (1990) have done so. But their analysis remains incomplete from our point of view, in the extent that they assume

that both types of firms are located in the CBD. Our concern is to study the spatial vertical disintegration. The most complete urban model with two sectors has been developed by Fujita and Krugman (1995). A lot of papers are based on it (Fujita and Mori (1997), Fujita *et alii* (1999)). But these are more regional than pure urban economics models: they all try to rebuild a Christaller's type system of cities. Fujita and Hamaguchi (2001) for example, concentrate on "monocentric configurations involving different patterns of trade". In this model, the cities are always monocentric but they evolve from an *integrated city equilibrium* to a *I-specialized equilibrium* as transport cost decrease. They study the two sectors among the cities rather than within the city. Indeed, they deal more with cities in a 'new economic geography' model than with a 'new economic geography' model in the city.

The way we look at the city in this paper put von Thünen and Chamberlin in a historical perspective. While the original city concentrates services and industries in the center, the IC tends to leave the center when the services are more and more specialized. The break of the vertical linkage then weakens the center of the city, leading to a city where services remain in the center while industries locate around it. This is typical of the post-WW2 cities: the CBD is located in the center and the IC are lying in the suburbs. Their location depends both on their need for land and on the transportation and exportation costs. But then, in the post-modern city, the location of services and industries tend to reconcile. This is to be understood as a consequence of the ever increasing cross relations between services and industry. As the importance of services in the production function overpasses these of the wages and the land, the industry will prefer a location closer to the services. If they have remained in the center, then the monocentric city would reappear. But this movement toward the center is no more a movement toward the center of the city (the point with the highest land rent) than toward the CBD. In our model, the location of the services will remain fixed. Thus, the IC locates back to the center as the economy is more and more services oriented and as these services are more and more specialized. What should be done as a next step would be to let the services locate wherever they want to.

The remainder of this paper is organized as follows. In section 2, we present the model. We develop a two sector model where the differences in the demand for land are crucial to understand the equilibrium. Namely, as the industry needs more land for its activities than services do, factories will be likely to find a suburban location more attractive. In order to simplify

the solution of the model, we have assumed that the demand for land of the services firms was negligible compared with that of the industry and the households. Hence, land is occupied by industry and households, and the need for land of the industry is a major centrifugal force. Note that our story begins when the industry firms and the services firms are already independent.

In section 3, we consider the different markets for intermediate services, for wages and for land. We then solve the model considering a monocentric city. Given this configuration and the equilibrium on the different markets, we work out the conditions on the parameters that make it possible for the configuration to be an equilibrium (in the sense of Nash equilibrium configuration defined by Ota and Fujita (1993)).

In section 4, we explore the results that come from our model. Especially, we look at how and why the monocentric city is sustainable when parameters change.

2 The model

The core of our model are the different needs for land and communication of the two sectors of our economy. Industry needs land and externalizes its need for information, whereas services firms do not need any land but improve their productivity through contacts with other firms. Therefore, the services firms face agglomeration externalities but do not have any demand for land while the industry is a constant return sector and uses land. Now, what characterizes the urban economics approach is the need for land. It's amazing that most of the urban models so far assume that only households and agriculture consume land. In such models, the location of a firm only affects its profits through the labor market. Actually, if we want to understand how an industry locates in the city, it seems important to consider not only that a firm plays a role in the land market through the labor market, but also that it acts directly on that one.

In our model, households are indifferent between the two types of jobs (in industries and services). All the services are sold to the industrial firm, and there is a Chamberlin type competition on the market for intermediate services. As written above, industrial firms have a demand for land, S . They also buy aggregate services, Q , and labor, L_2 , and they export their production at a price r . We assume that there are two different types of

transportation costs in the city. There are additive costs (the transportation cost — t) for the individuals (households and services) and iceberg costs for the exported goods (the exportation cost — τ). There is no agglomeration externality in the industry, therefore no sub-optimal lock-in situation is possible. On the contrary, there are high agglomeration externalities in the services. Each of the N services firms (N is endogenous) hires L_1 workers.

Our point is that once there has been a vertical disintegration the firms can choose the most appropriate location for their activity: they just take into account the needs for land of their specific sector, either services or industry. Hence, a specific location analysis will yield different results for an industrial firm and for a services firm. Actually and under some conditions, industries seem to leave the center of the city for its suburban areas, whereas services do not.

2.1 The city

The city is supposed to be linear, with absentee landlords. It is supposed to be centered in 0. It is also open so that the urban system as a whole reaches an equilibrium. This has three consequences on our economy. First, the households consume the same amount of imported composite good z^* as in the other cities. If it was not the case, people would find incentives to come in the city, or to leave it. Second, we assume that the city is sufficiently small on the market of exported goods, so that the industrial firms of the city are price taker (r is the price of the output). Third, there are L households ($L = L_2 + NL_1$) and the city ends at $e = \frac{L+S}{2}$. Hence the size of the city is endogenous and depends on the industrial production Y through the industrial land use.

The transportation cost only applies to all the places occupied by households, while industrial areas are supposed to be free from transportation costs. From the very point of view of transportation costs this is not a rough assumption, since it only means that the firms are indifferent between all the possible places in the cluster and that the households can cross the cluster without entering it¹. An immediate consequence is that industrial firms are

¹If we assume that there is a freeway through the cluster, the households can cross it far quicker than a residential area. Also, contrary to the residential areas, the transportation network within the cluster is adapted to the needs of the industry. Thus within the cluster both the transportation costs of persons and goods are neglectible compared with that of a residential area. Hence we consider here that the cost of entering or crossing a cluster is

concentrated without any need to assume externalities. Because all the firms are identical and because the differences between two possible locations only rely on the transportation costs, the best location will be chosen simultaneously by all the firms and there will be a new cluster². Hence we look at the existence of a monocentric Nash equilibrium in the city.

2.2 The households

Households work indifferently in the two sectors and must choose between the consumption of land (which is normalized to 1) and that of an imported composite good, z^* (whose price is normalized to 1 and is the numeraire of the economy). Since they work indifferently in one sector or the other, the L households manage first to choose their place of work. They decide the place where they want to live only in a second time, by maximizing their utility $U = U(z^*)$ considering the set of their consumption of land and composite good. There is only one worker per household and the only income the households get are their wages. We assume that the composite good is imported at a uniform price that includes the transportation cost. Therefore, the budget constraint of a household living in x and working at x_w is

$$W(x_w) = \Psi(x) + z^* + td(x, x_w),$$

with $W(x_w)$ the wage earned if the firm is located in x_w , $\Psi(x)$ being the land rent at x , $d(x, x_w) = |x_w - x|$ being the commuting distance, and t being the transportation cost.

Each household aims at maximizing its utility with regard to this constraint. Given an exogenous level of land use, each household will have to choose x so as to maximize its consumption of composite good. Hence, $\Psi(x)$ can be regarded as the bid rent of the household and it depends on x_w (Fujita (1989)). Then, given $W(x, x_w) = W(x_w) - t|x_w - x|$ the wage free from transportation cost, the bid rent of a household can be rewritten

$$\Psi(x, x_w) = W(x, x_w) - z^*.$$

nul.

²We assume here that all the firms decide to move at the same time and without any coordination. All firms being the same, a situation in which only a non neglectible part of the industry is moving is impossible.

2.3 The industry

The city exports an industrial good. It is produced by n industrial firms (n sufficiently high) and we assume that the competition between the industrial firms is pure. That is to say, we assume that when the disintegration occurs, the industry becomes nothing more than factories competing with each others. Whereas the services keep a non competitive aspect due to the variety of their production, the process are the same among all the industrial firms. Hence, there are no agglomeration forces that influence the location of the industrial firms.

The IC is located between b and $b + \frac{S}{2}$. Both wages and land rent are not influenced by the relative location of the firms within the cluster then all the prices will be set as for an IC located at b . As a whole, the industrial sector produces

$$Y = \min \left\{ \frac{S}{\bar{s}}, Q^\lambda L_2^{1-\lambda} \right\}. \quad (1)$$

There, \bar{s} stands for the land productivity (from the industry point of view) and λ characterizes how much the industrial production is externalized to the services firms. q_i being the amount of services sold by the i^{th} of the N firms, the overall services consumption is

$$Q = \left(\sum_{i=1}^N q_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

where σ is the substitution elasticity between the services. Hence $\sigma > 1$, and as it increases, the services are more and more substitutes with each others. Now, $\rho = \frac{\sigma-1}{\sigma}$ stands for the preference for variety ($0 < \rho < 1$) and the higher the substitution elasticity the lower the preference for variety (ρ high).

The industry profit is then

$$\Pi_2(b) = \tau(e-b)rY - S\Phi(b) - W(b)L_2 - \sum_{i=1}^N p_i q_i$$

where τ is an iceberg cost. It stands what remains from a production once it has been carried out on a given distance. Hence, the lower τ the higher it costs to export a product from the center to the edge of the city. The part of the budget the industrial firms dedicate to both wages and intermediate services $T(b) = \tau(e-b)r - \bar{s}\Phi(b)$ clearly depends on the location of the cluster. For example, a central location will increase the price of the land and

the losses due to the transport through the city. Now we need to consider the intermediate consumption as a whole. If we minimize the cost of the aggregate services Q , we reach

$$\sum_{i=1}^N p_i q_i = \left(\sum_{i=1}^N p_i^{1-\sigma} \right)^{\frac{1}{1-\sigma}} Q. \quad (2)$$

From now on we will consider $P = \left(\sum_{i=1}^N p_i^{1-\sigma} \right)^{\frac{1}{1-\sigma}}$ as the price index of the aggregate services. With $\sum_{i=1}^N p_i q_i = PQ$, the industrial sector maximizes its profits with regard to the technical constraint (1). Thus we reach the following solution,

$$\begin{aligned} S &= \bar{s}Y \\ L_2 &= \frac{1-\lambda}{W(b)} T(b) Y \\ Q &= \frac{\lambda}{P} T(b) Y. \end{aligned} \quad (3)$$

We also find out that classical result, $T(b) = \left(\frac{W(b)}{1-\lambda} \right)^{1-\lambda} \left(\frac{P}{\lambda} \right)^\lambda$. As profit must be nul at equilibrium we can express the industrial land rent as what is left for the industry once services and labor have been bought. Using all the preceding results on S , L_2 , Q and $T(b)$,

$$\Phi(b) = \frac{\tau(e-b)r}{\bar{s}} - \frac{1}{\bar{s}} \left(\frac{W(b)}{1-\lambda} \right)^{1-\lambda} \left(\frac{P}{\lambda} \right)^\lambda. \quad (4)$$

This corresponds to the industry willingness to pay. For the land use pattern of the city to be an equilibrium, it must be equal to the land rent at the places occupied by the IC. It naturally depends on the earnings of the industry minus its costs, both labor costs and services costs.

2.4 Services

It has become common to assume externalities in the production of certain types of goods (Lucas (1999), Anas *et alii* (1998)). Here as well each services firm finds an advantage to be located near the others. When one locates out of the CBD, the over-productivity of the workers decreases down to zero. But if it sets up near the CBD (which is supposed to be located at a), it will

benefit from the proximity of its competitors. With k being a fixed cost and $\delta > 0$ setting the importance of the externalities, the production of the i^{th} services firm is then

$$q_i = f(L_{1,i}, a, x_i) = \left(1 + e^{-\delta|x_i-a|}\right) L_{1,i} - k.$$

Using the exponential form, the higher δ , the lower the externalities. When all the services firms are clustered, the externalities are maximum. When one firm locates very far from the other the effect of the externalities on the production are nul. it is the case when x_i tends to be infinite. In that case, the services firm are less productive than the industry because they have to overcome the fixed costs. If all the services firms are clustered, the agglomeration effects can compensate the fixed cost. In that case when $e^{-\delta|x_i-a|}L_{1,i} > k$ the services firms are more productive than their industrial counterparts. Thus, depending on the relative locations of the two clusters the industrial firms can find an advantage in partly externalizing their production.

Considering that the price of the services includes the delivery to the IC, the profit of a services firm is

$$\pi_{1,i}(x_i) = p_i q_i - [t(b - x_i) + W(x_i)] \frac{q_i + k}{1 + e^{-\delta|x_i-a|}}. \quad (5)$$

An increase in the fixed cost will necessarily affect the profit of the firm, as well as an increase of the loss of productivity that follows a shift from the CBD. An increase in the transportation cost will directly affect the profit of the services firm since it increases the delivery price. By the way, it will also increase the wages this second effect reinforcing the direct one. Also, when the IC locates far from the services, the delivery price increases and this effect downgrades the profit of the services firms through a substitution effect. But there is also an income effect due to the increase of the production. We now turn to the equilibrium on the market for intermediate services to look at this effect.

3 Solution

3.1 the market for intermediate services

The production of the services firm is exclusively dedicated to the industry. Given the preference for variety and the oligopolistic competition on the

services side, the industrial firms address to each services firm a demand that depends on the prices index P , the overall demand D , the price of the i^{th} variety and the substitution rate among all the services, σ . Considering (2), this leads to the following production constraint

$$q_i = \frac{p_i^{-\sigma}}{P^{-\sigma}} Q. \quad (6)$$

Now, the i^{th} firm maximizes its profit (5) with regard to the price of its services p_i :

$$\max_{p_i} \pi_{1,i} \quad \text{s.c.} \quad q_i = p_i^{-\sigma} (\lambda T(b) Y)^\sigma Q^{\sigma-1}.$$

At equilibrium, all the firms are agglomerated at a , hence $x_i = a$ ($\forall i$). Since they produce the same amount of services and sell them at the same price, the equilibrium price $p_i = \bar{p}$ ($\forall i$) can be find out and the equilibrium quantity $q_i = \bar{q}$ ($\forall i$) can be derived:

$$\begin{aligned} \bar{p} &= \frac{\sigma}{\sigma-1} \frac{t|b-a| + W(a)}{2} \\ \bar{q} &= (\sigma-1)k. \end{aligned} \quad (7)$$

We verify the classical result according to which the services sold by each firm at equilibrium do not depend on the size of the production. They are just related to the importance of the fixed costs and that of the preference for variety. If the production increases, there just will be an increase in the number of firms. With (3) and (6), we calculate

$$N\bar{p}\bar{q} = \lambda T(b) Y, \quad (8)$$

that is to say

$$N = \frac{2}{\sigma k t} \frac{\lambda T(b) Y}{|b-a| + W(a)}.$$

3.2 The industrial production

There is no unemployment in the city and the population works either for the industrial firms or for the services firms. Given the population and the needs of both industry and services, we will be able to split the L workers into L_2 industry workers and NL_1 services workers. The way this split is completed will then determine the production exported by the city Y .

We calculate the number of industry workers using (8) in $\Pi_2(b)$ and considering that it is nul at equilibrium:

$$L_2 = \frac{(1 - \lambda) Y T(b)}{W(b)}. \quad (9)$$

Now, as we know

$$NL_1 = \frac{\lambda T(b) Y}{t|b - a| + W(a)}, \quad (10)$$

we can express Y as directly linked with the size of the population and the economic structure (through σ and λ). Using the two preceding equations in the definition of L , we find that the production depends on the size of the population and on the split between industrial workers and services workers.

$$Y = \frac{L}{\left(\frac{1-\lambda}{W(b)} + \frac{\lambda}{t|b-a|+W(a)}\right) T(b)}.$$

As a specific wage is associated to each place, a relocation of the CBD or the IC will modify the wage pattern and change the entire production of the city. A relocation of one or both of the clusters will have a price effect through the relative wages and an income effect through the budget constraint.

Lemma 1 In the case of a monocentric city, the cost curves of the industry are homothetical.

When the city is monocentric, $W(b) = t|b - a| + W(a)$, and then the production can be written $Y = \frac{LW(b)}{T(b)}$. In that case, the income effect just influences the production. If it is not monocentric, then $t|b - a|$ is positive and the income effect influence on wages and services is not symmetrical.

The distance between the IC and the CBD will also influence the delivery price of services thus modifying the production at equilibrium. Also, these location have an influence through the transportation costs. The congestion (high transportation and exportation costs) has three effects on the city. First it lowers the earnings of the households. Second it increases the delivery price of services. And third, it directly lowers the earnings of the industry through the decrease of the sales. Note that here, this last effect has no influence on the production rather on the structure of the city. Indeed, an increase in the exportation cost will just lower the income of the firm thus decreasing its willingness to pay for land for a given production. As there is

no unemployment in our economy, there is no adjustment of the quantities. Then, an increase in the exportation cost will lower the land rent of the industrial firms until it becomes inferior to that of the households.

3.3 Equilibrium on the labor market: the case of a monocentric city

As the overall population of the city is fixed and because we assume that there is no unemployment in the city the labor market is solved through an adjustment of the production Y . Hence the equilibrium wage will just depend on the relative locations of the employment center (IC and CBD). We now turn to the specific case of the monocentric city which is the historical setting when the disintegration occurs. Of course, the location of both the CBD and the IC immediately determines the wages pattern.

In the case of a monocentric city, the wages free from transportation costs $W(x, x_w)$ are strictly decreasing as the household is located near the edge of the city: it costs more and more to reach the center. On the edge what remains to the households, once the equilibrium consumption has been bought and the transportation paid for, just equals the cost of opportunity of the land, usually its agricultural productivity. We assume here that this cost is equal to zero. Then

$$W(0) - t\frac{L}{2} = z^*.$$

Now we can solve the system in the case of a monocentric city and we reach

$$\Phi(0) = \frac{\tau Lr}{\bar{s}} - \frac{W(0)}{\bar{s}} \left(\frac{1}{1-\lambda}\right)^{1-\lambda} \left(\frac{L}{k}\right)^{\frac{\lambda}{1-\sigma}} \left(\frac{2\lambda}{\sigma}\right)^{\frac{\sigma\lambda}{1-\sigma}} \left(\frac{1}{\sigma-1}\right)^\lambda,$$

$$W(0) = z^* + \frac{tL}{2},$$

$$\text{and } Y = L^{\frac{\sigma+\lambda-1}{\sigma-1}} (1-\lambda)^{1-\lambda} \left(\frac{2\lambda}{\sigma}\right)^{\frac{\sigma\lambda}{\sigma-1}} \left(\frac{1}{k}\right)^{\frac{\lambda}{\sigma-1}} (\sigma-1)^\lambda.$$

A few characteristics of these first results should be emphasized.

Lemma 2 *The land rent the firms offer positively depends on both the externalization of the economy and the specialization of the services.*

This means that the more the industry needs services, the higher the land rent ($\frac{\partial \Phi(0)}{\partial \lambda} > 0$). Also, when the industry has a greater preference for variety the land rent is higher ($\frac{\partial \Phi(0)}{\partial \sigma} < 0$). These two parameters are crucial to our model since they have a real influence on the economy, contrary to the transportation costs which have a more binary effect.

Remark 1 Whatever the location of the CBD and the IC, what the city produces and exports does not depend on the specific exportation cost. In the very case of the monocentric city, the transportation cost neither influences the production.

Thus the transportation and exportation costs determine if the city can produce for the outter market (and then exist) or not. If they are too high, the city will not be competitive enough. Considering the population as given, the production will decrease to zero when the congestion increases and the city might disappear. The transportation cost are crucial to understand if the city exists or not because they affect the land rents and the earnings of households and firms. But once the city exists, they just have a nominal effect.

Remark 2 An increase in the size of the city will raise the production. But as the city goes bigger and bigger, the returns are decreasing.

Proof: It comes naturally from the expression of Y that $\frac{\partial Y}{\partial L} > 0$ and $\frac{\partial^2 Y}{\partial^2 L} < 0$.

We turn now to the effect of more structural changes in the economy: either a change of the preference for variety of the industry or a change of the externalization of the production to the services. The first point just states that the services get more and more specialized, since the preference for variety is directly linked to the substitution rate among services ($\rho = \frac{\sigma-1}{\sigma}$). A rather simple justification for such an event is that as globalization rises, the industry should be more and more on the edge of the technology, then looking for more and more varieties in services.

Proposition 1 When the services get more and more specialized (i.e.: the preference for variety increases) the production of the city also increases.

Proof: (see Appendix 1)

An increase in the preference for variety reduces the price index. This makes the industry more productive by both shrinking the overall cost of services and the wage bill (through an increase in the services demand). Through a simple price effect it increases the demand of the industry to the services sector. As far as services firms are concerned, this firstly leads to an increase in the number of variety (i.e.: the number of firms). But secondly the competition is fiercer among the existing firms and finally their size decrease. The importance of this decrease will depend on the level of the preference for variety of the industrial firms, the lower the preference for variety, the fiercer the competition.

Proposition 2 The overall production of the city usually increases as the industry externalizes more and more of its production to the services firms.

Proof: (See Appendix 2)

The movement toward a more and more services oriented production characterizes the twentieth century. In the model, the production of the city regarding the externalization ($\frac{\partial Y}{\partial \lambda}$) is always increasing and it is always positive for common values of the parameters. When considering extreme values of the other parameters of the economy, it may be negative only for an integrated production system, when λ is very low. But these cases correspond more or less to a pure industrial economy. For most of the realistic cases, an increase in the externalization of the production (increase of λ) will increase the production of the city. We stand here in such conditions that the services firms are more effective than the industrial ones and replacing working people by services will increase the effectiveness of the city (note that we remain in the context of a zero-unemployment economy). The city being more effective as λ increases, the more services the greater the production.

4 Results

The history of our model begins with the break of the vertical linkage between the services and the industry. At this moment, all the firms are supposed to be clustered in the center of the city and we study what happens then : we focus on how the industry is likely to relocate and what could be the new configuration when the economy evolves both toward more specialized services and toward a more services oriented production.

We first set the conditions for an equilibrium to be possible given the characteristics of the economy. Once this has been done, we check if the land use pattern is a Nash-equilibrium after the break of the vertical linkages between industrial and services firms.

The monocentric city is likely to exist only if the land rent an industrial firm offers is higher than that of the households in the center of the city. The land rent of the households both depends on the wages and on the size of the city. Because there are no transportation costs in the IC, the size of the city is given once the population has been fixed. Then as we said it before, the transportation and exportation costs but also the price of the industrial good will only have nominal effects. An increase in the price of the industrial good or a decrease in either the transportation cost or the exportation cost will increase the land rent of the industry. Hence, we reach a minimum condition on the price of the industrial good (and the exportation cost), so that the city exists,

$$\Psi(0) < \Phi(0) \Leftrightarrow \tau r > \frac{\bar{s}t}{2} + \frac{2z^* + tL}{2L^\sigma} \left(\frac{L}{1-\lambda} \right)^{1-\lambda} \left(\frac{(2\lambda\sigma)^{\frac{\sigma}{\sigma-1}}}{\sigma-1} k^{\frac{1}{\sigma-1}} \right)^\lambda.$$

Now, the city remains monocentric as long as the industrial firms do not find any incentive to relocate. This happens when there is a location x' in the city such as $\Pi(0) < \Pi(x')$. We suppose that the industrial firms are blind in that they ignore what the other firms do. Since a relocation choice is really strategic, it seems a fair assumption: each firm secretly decides a new location. Our purpose is the existence of a monocentric equilibrium. Hence, we will not study if the new location is an equilibrium once all the firms have relocated.

There are n atomistic industrial firms. The relocation of a single firm will not affect the different equilibria of our economy, but it will change the program of the very firm. This one will have a specific demand for labor l_2 and a specific demand for services q given the new prices of both the labor ($W(x)$ instead of $W(0)$) and the services ($\bar{p} + tx$ instead of \bar{p}). Note that in the remainder, the small letters characterize the values for a single industrial firm. Then the program of a single industrial firm is

$$\pi_2(x) = \tau(L-x)ry - \bar{s}y\Phi(x) - W(x)l_2 - N(\bar{p} + tx)q$$

and it optimizes it with regard to the technical constraint $y = l_2^{1-\lambda}q^\lambda$. Solving the program, we reach the following condition according to which the firm will

not find any interest to leave the center as long as $C(x, 0) = \pi_2(x) - \pi_2(0) < 0$. Now,

$$C(x, 0) = -\tau r y x + \bar{s} y x t + t l_2 x - N t q x.$$

When a firm relocates, its land rent, its wages, as well as the price it pays the intermediate services and its earnings do change. Once given how the industry externalizes its production (λ), both wages and services only affect the profit through their relative prices. The earnings and the land rent at x determine the budget constraint. The global effect of a relocation both depends on this income effect and on the preceding price effect. This global effect depends linearly on the distance between the new location and the IC if and only if the cost curves of the industry are homothetical. Then the income effect has no effect on the relative consumptions of wages and services. If the city is monocentric, we stand in this case (*see*: Lemma 1) and the condition linearly depends on x . Using (9) with (8) and (7) and l_2 and q from the solution of the program,

$$C(x', 0) = 0 \Leftrightarrow$$

$$x' = \frac{(\tau r - \bar{s} t) \frac{W(0)}{\rho} - \left(\frac{1-\lambda}{\rho} - 2\lambda\right) t T(0)}{\left(2(1-\lambda) - \frac{\lambda}{\rho}\right) (\bar{s} t - \tau r) W(0) + 2t T(0)} \frac{W(0)}{t}.$$

If $x' < 0$ the monocentric city will be an equilibrium because no industry firm finds any interest in leaving the center. If $0 < x' < L/2$, the IC will leave the center and relocate on the edge of the city where its profit will be maximum. If $x' > L/2$ and considering that the transportation costs are nulls within the IC, the monocentric city is also an equilibrium.

As noted above, the transportation costs just act as conditions for the city to exist as a production center. Now if we look at the relative locations of the IC and the CBD, they highly depend on the preference for variety of the industry firms and on the externalization of their production toward the services firms.

All things equal, a higher λ means that the industry firms use more and more services rather than employees. The wages being a centrifugal force in our model while services are a centripetal one, the more externalized the economy, the more likely a monocentric configuration. But when the city is a quasi pure industrial one the land rent is very low. Hence the central location can also be attractive for low values of λ .

The preference for variety of the industry mostly has an influence through the price index of the services. Namely, an increase in the preference for variety will increase the price index and the relative importance of the centripetal force. Thus, for high values of σ when the services are specialized, the monocentric equilibrium will be more sustainable.

Also a change in the function of production changes the overall production and then the budget constraint. The consequences of this income effect highly depend on the cross relations between externalization and specialization. Now, we have remarked that all things equal an increased externalization of the production to the services firms increases the production of the city. For low values of λ , these cross effect will be highly negligible.. But as the industry turns more and more toward services firms, the importance of the income effect will increase.

Remark 3 As the specialization of the services or externalization of the production to services increase, three types of states appear. In the first one the monocentric equilibrium exists. In the second one industry firms tend to leave the center and to locate around the city. Finally the monocentric city is an equilibrium again because the IC relocates close to the CBD.

Definition 1 A city is an industrial city when industry and non-specialized services are located together in the center.

It is a modern city when the industry is located around the city and partly externalizes its production to services firms.

The post-modern city is characterized by the co-location of the IC and the CBD. The production is highly externalized to specialized services firms.

Considering the evolution of x' as specialization and externalization change (with the following parameters $L = 1,000,000 : z^* = 4 : \tau = 0.9 : r = 5 : S = 1.2 : k = 2$ and $t = 0.2$), three regimes of cities appear (Figure 1).

<Insert Figure 1>

The first one corresponds to the industrial city (1), when the city is mostly industrial and the services are not specialized. In that traditional city, the industry is located around the center and the production is highly integrated. If the city is mostly industrial, the land rent is not very high. If the preference for variety is also low, then it makes it easier for an industry firm to remain in the center. But either if the industry externalizes more of

its production to services firms or if the services are getting more specialized, the production and the prices will raise in the city. Thus the monocentric city could no more be an equilibrium mostly because of the income effect. This explains the monotony of the transition between the first and the second case. Historically, this transition corresponds to the roaring twenties in the USA and the fifties in Europe, the turning point being the development of the mass production.

The second regime is that of the modern city (2). The industry leaves the center and settles around the city, looking for land and accessibility. Due both to an emerging disintegration of the production and to the growing importance of more specialized services, the production of the city increases. Without any size effect (the population remains constant in our model), but via the income effects on wages the land rent increases in return. This leads to a city where the services are gathered in the CBD while the IC locates on the edge where land is more affordable. J.Garreau depicts it well when he deals with the case of Detroit. He writes,

“... it offered far more land than the old down-town both for expansion — and parking. Right there, in New Center, immediately after World War 1, Edge City was probably born. Henry Ford’s company followed suit. When he switched production from the Model T to the Model A in 1928, he also switched his *factory* location from Highland Park (...) to the plains of Dearborn.”

But if this movement goes on, there is a stage when the centripetal force of the services overpasses the centrifugal forces of both wages and land rent. Thus the industry firms find no more incentives to leave the CBD. Once again, an increase in the specialization of the services acts the same way. But this transition is far less monotonous than the preceding one. As the industry externalizes a growing part of its production to the services firms, more and more substitution effect influence the production of the city and the profit of the industry firms. Hence, the transition from the second to the third regime is no longer ordinary. There is a critical area (**A**) where no single way path is guaranteed and its possible to have cities going from type 2 to type 3 and then back to type 2 as the specialization of services increase. This critical path well characterizes the variety of the cities of today. Depending on their relative history and industrial specialization, they are differently integrated and their dedicated services are also differently specialized. Hence, their path from the second to the third regime are different.

The third regime is the post-modern city (3). The industry are back in the city. But this come back is not driven by a recovered productivity that could increase the land rent the firms offers. As it externalizes more and more of its production to the services firms the industry reinforces the centripetal forces that links the IC and the CBD. The growing importance of the services increases this centripetal forces that finally overpasses the centrifugal effect of both wages and land rent. Then there are integrated clusters around the CBD as in lot of contemporary American cities.

We focus here on the way externalization and specialization interact. Of course, the other parameters influence the evolution as well. An increasing transportation cost, for example, leads to faster succession of the three regimes: the shift from type 1 to type 2 occurs for lower values of λ and higher values of σ (see: Figure 3 in Appendix 3). As well, for extreme values of the exportation cost or the need for land, some cases may totally disappear (Figure 4).

5 Conclusion

In the huge metropolitan areas, there is a joint movement toward suburbanization of the industry and specialization of the services. We have developed a model explaining the consequences of both of these evolutions on urban development. We understand the evolution of the city from its industrial age to the post-modern figure of Los Angeles through the evolution of the vertical relations between industry and services.

The vertical disintegration in the industry makes it possible for the different sectors to chose their location according to their own criteria. Hence, even if there remains a vertical relation between separated firms, there may be a spatial disintegration in the urban space. In our model, as in most of the urban economics models, the multipolarization of the city comes from a comparison between the centrifugal and the centripetal forces. The transportation cost plays an important role in the solution of the model. As usually, it is a centrifugal force since it leads to an increase in the land rent and the wages paid at the center. As we consider that industry needs land, industry might leave the center. But if we combine it to vertical relations linking the industry and the services, then a centripetal force appears. It reinforces when the economy is more and more services oriented.

The joint introduction of the vertical linkages and of the specific demands

for land leads us to an original approach of the urban development history. The industrial city was a city where industry was mostly integrated and services not extremely specialized. It corresponds to our first regime, when the monocentricity is an equilibrium. In the first part of the twentieth century the mass production system has appeared along with a growing externalization of the industry and a specialization of services. This has led to the modern city, where the CBD remains in the center while the IC locates around the city. But as both of these changes go on, the growing importance of the services tends to overpass that of the wages or that of the land rent in the location choice of the industry firms. Thus the post-modern city appears where industry and services are melted.

But if we want to understand clearly this last regime, we need to free the location choice of the services. By doing this, we could obtain not three but four regimes. The two first remaining unchanged, there could be a regime where services firms may leave the center for suburban areas. Hence, the final regime would be characterized by an agglomeration of the IC around a specialized CBD that would no longer be in the center, as it nowadays usually appears. This part is under work

Finally, note that we have remained here in the case of a unique city. Consider now that while there is an externalization and a specialization of the services there is also a specialization of the cities within an economic region as Fujita and Hamaguchi (2001) clearly worked it out. The primacy city will be more services oriented than the other cities and will also develop specialized services the others will not. Hence, within a single economic region there could be different types of organization for cities of higher and lower ranks. For example, the central agglomeration would follow the modern regime of organization before the other cities. Thus, and apart from differences in size, we could explain why there are specific urban regimes in the same region depending on the rank of the city in the regional hierarchy.

6 Appendix 1

When the preference for variety of the industry changes, its production

$$Y = L^{\frac{\sigma+\lambda-1}{\sigma-1}} (1-\lambda)^{1-\lambda} \left(\frac{2\lambda}{\sigma}\right)^{\frac{\sigma\lambda}{\sigma-1}} \left(\frac{1}{k}\right)^{\frac{\lambda}{\sigma-1}} (\sigma-1)^\lambda$$

changes too, and we reach

$$\frac{\partial Y}{\partial \sigma} = e^{\lambda \ln(\sigma-1)} \frac{e^{\frac{\sigma+\lambda-1}{\sigma-1} \ln L} e^{(1-\lambda) \ln(1-\lambda)} e^{\frac{\sigma\lambda}{\sigma-1} \ln 2\lambda}}{e^{\frac{\sigma\lambda}{\sigma-1} \ln \sigma} e^{\frac{\lambda}{\sigma-1} \ln k}} \frac{\lambda}{(\sigma-1)^2} \ln \frac{\sigma k}{2\lambda L}.$$

The sign of the preceding expression can then be determined with

$$\begin{aligned} \frac{\partial Y}{\partial \sigma} > 0 &\Leftrightarrow \ln \frac{\sigma k}{2\lambda L} > 0 \\ &\Leftrightarrow \sigma > \frac{2\lambda L}{k}. \end{aligned}$$

As long as $\sigma < \frac{2\lambda L}{k}$ (i.e.: a very high substitutability of the services) a decrease in σ (the preference for variety increases) will raise the production of the city. It is only for very high (and mostly unlikely) values of σ ($\sigma > \frac{2\lambda L}{k}$) that an increase in the specialization (decrease in σ) is about to decrease the production of the city.

This case is mostly never happens because, with

$$N = \frac{2}{\sigma k} \frac{\lambda T(0) Y}{W(0)} = \frac{2\lambda}{\sigma k} L$$

we get

$$\frac{\partial Y}{\partial \sigma} < 0 \Leftrightarrow N > 1.$$

Hence, as long as there is a positive number of firms (that is to say as soon as the city exists...) an increase in the preference for variety will always have a positive effect on the production of the city. In order to understand the effect of a greater specialization on the structure of the services, note that

$$\frac{\partial N}{\partial \sigma} = -\frac{2\lambda}{\sigma^2 k} L < 0 \quad \text{et} \quad \frac{\partial \bar{q}}{\partial \sigma} = k > 0.$$

Then, if the services are more and more specialized, there will be both an increase in the number of services firms and a decrease in their size. And when the specialization increases, the number of variety effect gets more and more important compared to the size effect.

7 Appendix 2

When the industry externalizes its production, the production

$$Y = e^{\lambda \ln(\sigma-1)} \frac{e^{\frac{\sigma+\lambda-1}{\sigma-1} \ln L} e^{(1-\lambda) \ln(1-\lambda)} e^{\frac{\sigma\lambda}{\sigma-1} \ln 2\lambda}}{e^{\frac{\sigma\lambda}{\sigma-1} \ln \sigma} e^{\frac{\lambda}{\sigma-1} \ln k}},$$

the production evolves as follows:

$$\begin{aligned} \frac{\partial Y}{\partial \lambda} &= \frac{e^{\lambda \ln(\sigma-1)} e^{\frac{\sigma+\lambda-1}{\sigma-1} \ln L} e^{(1-\lambda) \ln(1-\lambda)} e^{\frac{\sigma\lambda}{\sigma-1} \ln 2\lambda}}{\sigma-1} \frac{e^{\frac{\sigma\lambda}{\sigma-1} \ln \sigma} e^{\frac{\lambda}{\sigma-1} \ln k}}{\sigma-1} \\ &\quad * \left(\sigma \ln \frac{2(\sigma-1)\lambda}{\sigma(1-\lambda)} + \ln \frac{(1-\lambda)L}{(\sigma-1)k} + 1 - \frac{\sigma}{2} \right). \end{aligned}$$

Hence,

$$\frac{\partial Y}{\partial \lambda} > 0 \Leftrightarrow \sigma \ln \frac{2(\sigma-1)\lambda}{\sigma(1-\lambda)} + \ln \frac{(1-\lambda)L}{(\sigma-1)k} + 1 - \frac{\sigma}{2} > 0.$$

For most of the realistic cases, this is verified. $\frac{\partial Y}{\partial \lambda}$ is negative only for very low values of λ when the economy of the city is quite entirely dedicated to industry.

<Insert Figure 2>

The evolution of the production regarding the externalization, $\frac{\partial Y}{\partial \lambda}$, is always increasing as we see it on Figure 1 for $L = 1,000,000$ and $k = 10$ and it is negative only for low values of λ and very high values of σ .

8 Appendix 3

<Insert Figure 3>

<Insert Figure 4>

References

- [1] Abdel-Rahman H and Fujita M, 1990, Product variety, marshallian externalities and city sizes, *Journal of Regional Science*, 33, 189-222.
- [2] Anas A., R. Arnot and K. Small, 1998, Urban spatial structure, *Journal of Economic Literature*, 36, 1426-1464.

- [3] Anas A. et I. Kim, 1996, General Equilibrium Models of Polycentric Urban Land Use with Endogenous congestion and Job Agglomeration, *Journal of Urban Economics*, 40, 232-256.
- [4] Delisle J-P, and Lainé F, 1998, Les transferts d'établissements contribuent au desserrement urbain, *Economie et Statistiques*, 311, 91-106.
- [5] Fujita M., 1989, *Urban Economic Theory, land use and city size*, MA : Harvard University Press.
- [6] Fujita M. and N. Hamaguchi, 2001, Intermediate goods and the spatial structure of an economy, *Regional Science and Urban Economics*, 31, 79-109.
- [7] Fujita M. and P. Krugman, 1995, When is the economy monocentric?: von Thünen and Chamberlin unified, *Regional Science and Urban Economics*, 25, 505-528.
- [8] Fujita M., P. Krugman and T. Mori, 1999, On the evolution of hierarchical urban system, *European Economic Review*, 43, 209-251.
- [9] Fujita M. and T. Mori, 1997, Structural stability and evolution of urban systems, *Regional Science and Urban Economics*, 27, 399-442.
- [10] Fujita M. and H. Ogawa, 1980, Equilibrium land use pattern in a non-monocentric city, *Journal of Regional Science*, 20, 455-475.
- [11] Fujita M. and H. Ogawa, 1982, Multiple equilibria and structural transition of non-monocentric urban configurations, *Regional Science and Urban Economics*, 12, 161-196.
- [12] Fujita M. and J-F. Thisse, 1996, Economics of agglomeration, *Journal of the Japanese and International Economics*, 10, 339-378.
- [13] Fujita M., J.F. Thisse and Y. Zenou, 1997, On the endogenous formation of secondary employment centers in a city, *Journal of Urban Economics*.
- [14] Garreau J., 1991, *Edge City*, New York, Doubleday.

- [15] Gilli F., 2001, Regional integration in Greater Paris. An approach based on commuting and industrial specialization, *LASERE-CORE*, decembre, 17, 2001.
- [16] Hansen N., 1990, Do producer services induce regional economic development?, *Journal of regional Science*, Vol. 30, No.4, pp. 465-476.
- [17] Henderson V., 1988, *Urban development: Theory, Fact and Illusion*, Oxford University Press.
- [18] Henderson V. and A. Mitra, 1996, The new urban landscape : developers and edge cities, *Regional Science and Urban Economics*, 26, 613-643.
- [19] Krugman P. and A. Venables, 1995, Globalization and the inequality of nations, *Quarterly Journal of Economics*, 110, 857-880.
- [20] Lucas R., 1999, Externalities and cities, *Review of Economics Dynamics*, forthcoming.
- [21] McLaren J., 1998, Globalization and Vertical Structure, Columbia University Department of Economics Working Paper.
- [22] Ota M. and Fujita M, 1993, Communication technologies and spatial organization of multi-unit firms in metropolitan areas, *Regional Science and Urban Economics*, 23, 695-729.
- [23] Scott A., 1987, Industrial organization and location: division of labor, the firm and spatial process, *Economic Geography*, 63, 215-231.
- [24] Steinnes , 1982, Do 'people follow jobs', or do 'jobs follow people'?, *Urban Studies*, 19, 187-192.

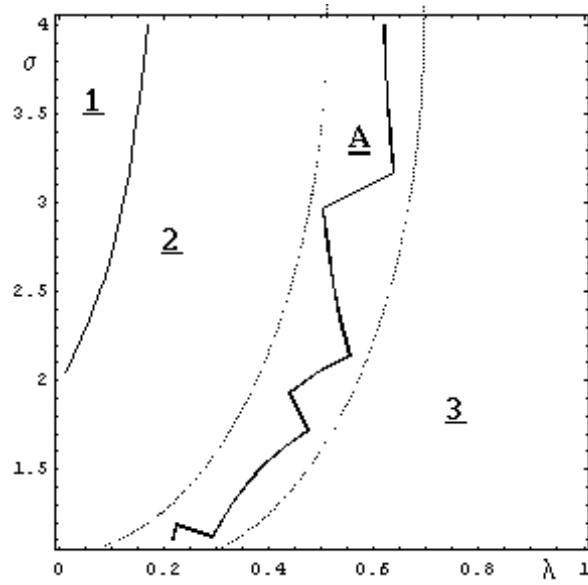


Figure 1: Three regimes of cities

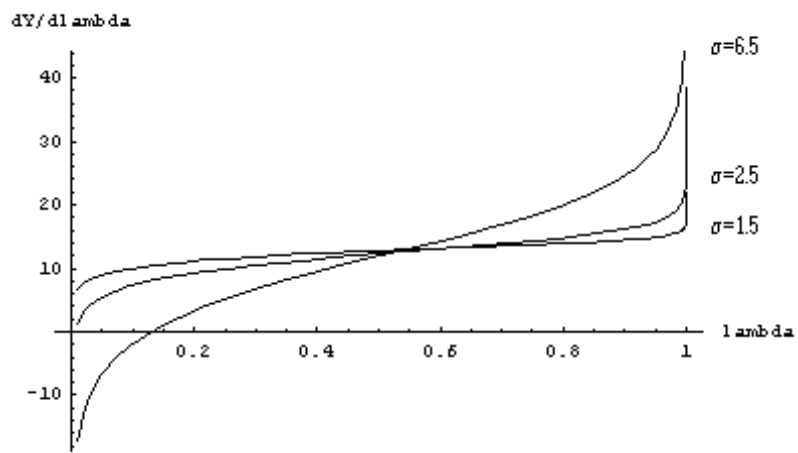


Figure 2: Production and externalization of the industry

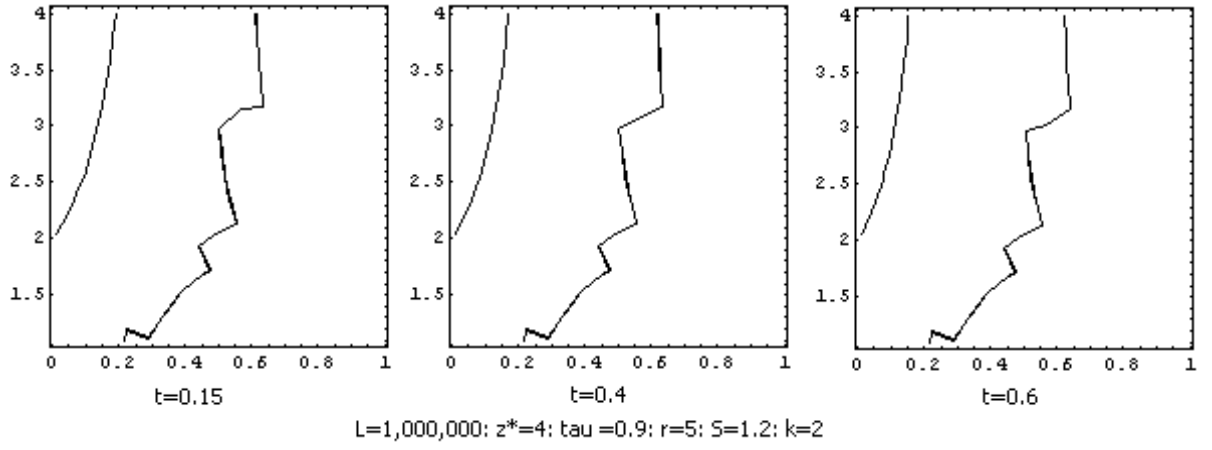


Figure 3:

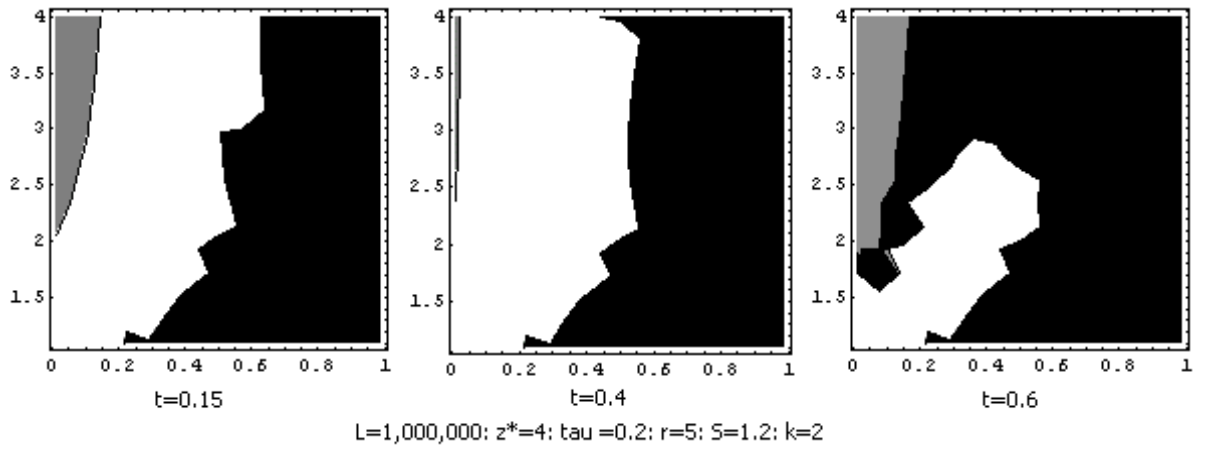


Figure 4: