Transport Costs and Rural Industrialization

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The aim of this paper is to determine what conditions producers of final (F) and intermediate (I) goods have incentive to locate or to remain in rural areas. A rural/urban general equilibrium model is built, in which the rural implantation of firms of the final and intermediate sectors depends on the relative costs of transporting goods to serve their respective markets. A reduction in the transport costs of intermediate goods encourages the dispersion of firms if the transport cost of final goods is high enough. When transport costs of F-goods are relatively high, the F-firms locate near final demand, which is spatially dispersed. And, when transport costs of I-goods are relatively low, the I-firms locate near F-firms, which, in this case, are spatially dispersed. Moreover, our findings supplement a number of results already reported in economic geography. For example, a U relationship is found between transport costs and share of industrial activities in rural region, if the fall in transport costs relates to I-goods and if the transport costs for F-goods remain sufficiently high.

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1. Introduction

Both the older and the more recent theories of industrial location emphasize that the presence of industry in rural areas is largely dependent on there being high transport costs. This "*reflects the old idea of Laundhart that the best protection for producers in the periphery is a 'bad road'.*" (Walz, 1996a, p. 177). These theories therefore predict that rural areas will lose their industrial fabric if transport costs fall (De Palma *et al.*, 1985; Krugman, 1991; Ottaviano *et al.*, 2002). Yet, despite a decline in transport costs, not only has a non negligible proportion of industrial production remained in the rural areas of developed countries but it has even grown over the last three decades (Bryden and Bollman, 2000; Doeringer, 1984; Goffette-Nagot and Schmitt, 1999).[1] Practice it is, not only the food industry but final and intermediate good producers too, that are located in rural areas. This paper investigates why are some industrial firms are prompted to locate or to remain in rural areas, in spite of a decline in transport costs.

In this paper, a general equilibrium model is developed, in which the rural implantation of firms of final and intermediate sectors depends on the relative costs of transporting goods to serve their respective markets. The model considers two regions with unequal endowments of labor force and three sectors for which the spatial allocation is endogenous. In the model presented here, agglomeration forces arise from final market size in the high-population region (urban region) and from the vertical linkages between the final good and the intermediate good sectors. Dispersion forces arise from the low labor cost in the low-population region (rural region) and the demand for the final goods by rural workers, who are spatially immobile. The originality of this work is to examine the effect of *relative* transport cost of industrial goods on the presence and the nature of industrial activities in rural areas. Most

[1] In France nearly one in four jobs in industry were in what are characterized as rural areas in 1998, which is more than a five-point increase since 1975.

works in Economic Geography assume identical transport costs for all industrial goods. But transport costs vary with the type of product (Combes and Lafourcade, 2001). It is legitimate to suppose then that relative transport costs should be allowed for when examining location decisions. A number of studies in the field of economic geography have analyzed how a relative reduction in transport costs for agricultural goods and final manufactures can disperse economic activity towards rural areas (Calmette and LePottier,1995; Kilkenny, 1998). However, rural industrialization cannot, today, be accounted for by restricting studies solely to the agricultural sector because this sector has become a minor sector in rural areas. We look at how transport cost differentials between intermediate and final manufactures affect the location of industry.

The present model is closely related to the spatial economy model of Fujita and Hamaguchi (2001), refered to as F-H model hereafter. Their model deals with location within a city and is thus more useful to for explaining the effect of differentials in transport costs between intermediate and final goods on urban spatial patterns. In their case, the dispersion force arises from the land market because agricultural workers are spatially dispersed since land is a necessary input. In contrast, in the present model, the centrifugal force arises principally from the labor market because there is competition between firms to attract workers, which are geographically immobile but mobile between sectors. Next, in this model, agglomeration arise from the *love for variety* not only on the final good producer side, as in the F-H model, also ont he consumer side. Moreover, the F-H model concentrates on the location of intermediate good sector. The final goods sector is spatially located *ex ante* and perfect competition prevails. Our analysis looks at the location of firms producing final and intermediate manufactures in monopolistic competition. And finally, from a methodological standpoint, the analysis presented here is opposite to F-H model because it focuses on the conditions of instability of agglomeration (and not stability) to determine when industrial sectors locate in rural region (and not in the city) and which.

The present model yields new results. A reduction in transport costs of intermediate goods encourages the dispersion of firms if the transport cost of final goods is high enough. When transport costs of F-goods are relatively high, the F-firms locate near final demand which is spatially dispersed. And, when transport costs of I-goods are relatively low, the I-firms locate near F-firms which, in this case, are spatially dispersed. Therefore, if the transport cost of intermediate goods is relatively low, some of producers of final and intermediate goods have an incentive to locate in rural areas. Moreover, our findings supplement a number of results already reported in economic geography. For example, a U relationship is found between transport costs and share of industrial activities in the rural region, if the fall in transport costs relates to I-goods and if the transport costs for F-goods are high enough.

These results arise from the assumption that labor is immobile between rural and urban regions. This assumption may be surprising, but seems adapted to the European context. Indeed, since 1975 migration from rural to urban areas has declined (Champion, 1998; Greenwood, 1997). The rural population has remained a relatively constant proportion of the total population, specially in Europe. Workforce mobility is generally low in Europe (Faini, 1999). Less than two per cent of workers change region per year. Adjustments within local labor markets as a result of regional shocks come about principally by participation levels in the European Union whereas in the United States adjustments are made by migration between regions (Decressin and Fatas, 1995).

Section 2 of this paper describes the theoretical model. The conditions, on the one hand, for F-firms to locate in rural areas, and, on the other hand, for I-firms to locate in rural areas are determined in section 3. Next, by crossing these two conditions, we determine, in section 4, the conditions for achieving rural industrialization whatever the type of industry. In this context, we study the consequences for rural industrialization of a fall in the cost of transporting F- (I-) goods for a given cost of transporting I- (F-) goods. Finally, section 5 determines the rural sectoral structure as determined by relative transport costs.

2. The model

Let us consider an economy composed of an urban region and a rural one (denoted by subscripts u and r, respectively). Let us suppose that the two regions are differentiated only by their available workforce, where $L_u = \lambda L_r$ with L_u (L_r) as the number of workers in the urban (rural) region and λ as a parameter greater than unity. We assume that the working population is immobile between regions but is mobile between sectors. Let us further consider that there are three sectors: an agricultural sector A, an upstream industry I manufacturing intermediate goods using labor as its only input, and a downstream industry F manufacturing final goods using goods I as its only input. Each industry is composed of a large number of firms whose employees and spatial distribution are endogenous. We can now go on to describe the characteristics of the working population and of the industries.

2.1 Working population

According to Dixit-Stiglitz (1977), each individual devotes a share $1-\gamma$ of his income to the consumption of agricultural produce A and γ to the consumption of an aggregate F of final goods. Cobb-Douglas preferences hold between the two types of good. The consumer's utility is then expressed as:

$$U = \gamma^{-\gamma}(1-\gamma)^{\gamma-1}A^{1-\gamma}F^{\gamma} \text{ with } F = \left(\int_0^{n^F} \left(q_i^F\right)^{\frac{\sigma^F-1}{\sigma^F}} di\right)^{\frac{\sigma^F}{\sigma^F-1}} \quad (1)$$

F is an aggregate composed of differentiated product. The F-sector therefore supplies a variety continuum of dimension n^F, q_i^F represents consumption of variety $i \in [0; n^F]$, and $\sigma^F > 1$ is constant elasticity of substitution between these varieties.

Transportation of F-goods from one region to another entails a Samuelson iceberg type transport cost τ_F. In this case, the local selling price is the mill price p^F, whereas the price of the good exported to the other region is $\tau_F p^F$. Thus, the budgetary constraint for a worker based in the rural area is written $w_r = A + P_r^F F$ where the agricultural good A is the *numéraire* and P_r^F is the industry price index of F-goods for the rural area:[2]

$$P_r^F = \left\{ n_r^F \left(p_r^F\right)^{1-\sigma^F} + \left(\tau^F\right)^{1-\sigma^F} n_u^F \left(p_u^F\right)^{1-\sigma^F} \right\}^{\frac{1}{1-\sigma^F}} \tag{2}$$

with n_r^F the number of F-firms in this region and p_r^F the price of F-goods in this region. Demand from rural and urban households on F-firms in the rural region is expressed at equilibrium as:

$$D_r^F = \gamma \left[Y_r \left(R_r^L\right)^{\sigma^F-1} + \left(\tau^F\right)^{1-\sigma^F} R_u^L \left(P_u^F\right)^{\sigma^F-1} \right] \left(p_r^F\right)^{-\sigma^F} \tag{3}$$

where R_r^L and R_u^L are the (endogenous) income of workers in the rural and urban areas, with:

$$R_r^L = w_r L_r \quad R_u^L = w_u \lambda L_r \quad \text{with } L_r = 1 \tag{4}$$

Each worker accepts to work in the sector offering the highest wage locally. There is therefore inter-sector competition for local labor. Consequently, the wage level in the rural economy (and reciprocally for the urban area) is given by:

$$w_r = \max \left\{ w_r^A; w_r^I \right\}$$

Wages offered by the I-industry must be higher than or equal to agricultural wages for the I-industry to be implanted in the region in question. The agricultural wage level can be

[2] Equations are shown for the rural region only. Simply changing the indices gives those for the urban region.

readily found. The production of one unit of agricultural good requires one labor unit L_a. The wage level in this sector w_a is therefore equal to the agricultural price, which is equal to unity. The agricultural sector A operates in a competitive market where a homogeneous good — the *numéraire* — is exchanged. If the industrial wage is identical to the agricultural wage, the sector composition of each region is to be determined. Conversely, if the local industrial wage is greater than 1, the A-sector is not located in the local economy. In this case, the wage of the rural region is equal to 1 as the existence of an A-industry in at least one region is laid down as a condition. Therefore:

$$w_r = 1 \quad \text{and} \quad w_u \geq 1 \tag{5}$$

2.2 Production

In the F-sector, the n^F firms operate in a market in monopolistic competition as described by Dixit-Stiglitz. We can reason in terms of a representative firm for each region. In producing F-goods, these firms use a unique aggregate I of I-goods, with constant elasticity of substitution σ^I ($\sigma^I > 1$). Technology is characterized by a fixed requirement α^F and a requirement β^F proportional to the level of production q^F as an input. We therefore assume that this sector does not use any labor factor in its production process. This assumption allows us to concentrate on how a firm decides between location close to final demand and location close to I-firms. The production function is expressed as:

$$I = \alpha^F + \beta^F q^F \quad \text{with } I = \left[\int_0^{n^I} (q_j^I)^{(\sigma^I - 1)/\sigma^I} dj \right]^{\sigma^I/(\sigma^I - 1)} \tag{6}$$

For simplicity, we use two normalisations, without loss of generality (since we are working with the continuum of varieties version of Dixit-Stiglitz): $\beta^F = (\sigma^F - 1)/\sigma^F$ and $\alpha^F = 1/\sigma^F$.

As with final consumption, importing an I-good gives rise to an iceberg type transport cost τ_I. The cost function of a rural firm is therefore:

$$c_r^F = P_r^I \left(\alpha^F + \beta^F q^F\right) \tag{7}$$

where P_r^I is the price index of the I-good for the rural region:

$$P_r^I = \left(n_r^I \left(p_r^I\right)^{1-\sigma^I} + \left(\tau^I\right)^{1-\sigma^I} n_u^I \left(p_u^I\right)^{1-\sigma^I}\right)^{\frac{1}{1-\sigma^I}} \tag{8}$$

where n_r^I is the number of I-firms in this region and p_r^I is the price of I-goods in this region. Each firm maximizes its profit $p_r^F q_r^F - c_r^F$ under its demand constraint ($D_r^F = k(p_r^F)^{-\sigma^F}$ with k a positive constant). The equilibrium price is therefore:

$$p_r^F = \frac{\sigma^F}{\sigma^F - 1}\beta^F P_r^I = P_r^I \tag{9}$$

Prices of F-goods are a mark up over production marginal cost and therefore vary with location. The number of I-firms has an impact on prices *via* the aggregate input price index. The more firms there are in the I-sector, the greater the fall in prices of I-goods and therefore in the price of F-goods.

The level of supply of F-goods per firm is determined on the basis of free entry, which implies an absence of profit:

$$q_r^F = \frac{\left(\sigma^F - 1\right)\alpha^F}{\beta^F} = 1 \tag{10}$$

Let us now look at the I-sector. This sector comprises n^I firms supplying differentiated goods produced under an increasing returns technology in a market under Dixit-Stiglitz monopolistic competition. Each firm uses a quantity l^I of labor. Technology is characterized by a fixed α^I and a variable β^I requirement depending on the level of labor output q^I. The production function is written:

$$l_r^I = \alpha^I + \beta^I q_r^I \quad \text{with } l_r^I = L_r^I / n_r^I \tag{11}$$

where L_r^I is the number of I-sector workers. The cost function of a firm I in the rural area is therefore:

$$c_r^I = w_r^I \left(\alpha^I + \beta^I q_r^I\right) \tag{12}$$

Regional demand for labor is expressed:

$$L_r^I = n_r^I p_r^I q_r^I / w_r^I \tag{13}$$

Finally, as with the F-industry (eq. 3, 9, and 10) and using two normalisations ($\beta^I = (\sigma^I - 1)/\sigma^I$ and $\alpha^I = 1/\sigma^I$), the prices, quantities supplied, and demand for I-sector goods is determined by:

$$p_r^I = \frac{\sigma^I}{\sigma^I - 1}\beta^I w_r = w_r \tag{14}$$

$$q_r^I = \frac{\left(\sigma^I - 1\right)\alpha^I}{\beta^I} = 1 \tag{15}$$

$$D_r^I = \left[R_r^F \left(P_r^I\right)^{\sigma^I - 1} + (\tau_I)^{1-\sigma^I} R_u^F \left(P_u^I\right)^{\sigma^I - 1}\right]\left(p_r^I\right)^{-\sigma^I} \tag{16}$$

where R_r^F and R_u^F are the (endogenous) total sales of rural and urban F-firms:

$$R_r^F = n_r^F p_r^F q_r^F \quad \text{and} \quad R_u^F = n_u^F p_u^F q_u^F$$

Having set out the characteristics of the various agents and the linkages between them, we now move on to describing the agglomeration and dispersion forces that come into play.

2.3 Dispersion and agglomeration forces

The different mechanisms governing the distribution of activities as captured in the model are identified. There are three agglomeration forces. The first is the market size effect of F-goods in the urban region induced by the unequal geographical distribution of population. Savings on transport costs mean that the level of demand from households is higher when firms are located close to them (eq. 3), as in the model of Krugman (1991). Profit levels are then higher and then F-firms are encouraged to locate in the more populous area as there are more outlets. The other two centripetal forces arise from vertical linkages between firms, similar to the model of Venables (1996). On one hand, the increased number of I-firms in a region reduces the I-good price index (eq. 8) and therefore the cost of production (eq. 7) of F-firms', whose profit increases. We are dealing here with a downstream link between firms in the F- and I-sectors. On the other hand, the increased number of F-firms in a region increases, all else being equal, local industrial demand (eq. 16), which is reflected by increased demand on each I-firm, leading to increased profit for these firms. This is an upstream linkage between I- and F-sector firms. The existence of vertical linkages encourages groupings among industrial firms. Consequently, agglomeration occurs in the region which has the advantage in terms of population size, that is, the urban region.

Nonetheless, there are forces working against agglomeration. Indeed, the agglomeration of firms generates two dispersion forces. First, the arrival of a new I-firm in a region brings about greater local demand for labor forcing up local wage levels (eq. 13) because the local labor supply is fixed. Likewise the implantation of F-firms also encourages the arrival of I-firms, thereby increasing wage levels. Second, the increase in the number of local I- and F-sector firms reduces the price indexes (eq. 2 and 8). Consequently, at given price and spending levels, local demand for each F-good (eq. 3) and I-good (eq. 16) will be lower. Competition on the local labor and goods markets tends to promote the dispersion of the I-industry, as in the model of Krugman and Venables (1995).

If the agglomeration and dispersion forces are not completely new, the originality of this work is that spatial equilibrium depends on *relative* transport cost of industrial goods. In what follows we determine the conditions for rural industrialization depending on relative transport costs.

3. When do industrial activities disperse?

What are the conditions, for at least one industrial firm, whatever its activity, to set up in a rural area? In order to answer this question, the total concentration of F- and I-firms in the urban area is fixed *ex ante* and the instability of this equilibrium is analyzed. By proceeding in this way, the conditions for industrialization as a function of relative transport costs are specified. This process also produces non-numerical, analytical results contrary to most Krugman-type models.

3.1 Total agglomeration

Let us consider first the situation where all firms (F-firms and I-firms) are concentrated in the urban area. This implies that income from the I-industry situated in the urban area equals spending by the F-industry (I-goods are the only input of F-firms and there is non loose in transportation). For F-firms, outlay is equal to income, or $n_u^F p_u^F q_u^F = n_u^I p_u^I q_u^I$, and equivalent to the budget that households devote to these goods, that is, $n_u^F p_u^F q_u^F = \gamma(1 + w_u\lambda)$. For I-firms, income is paid back in full as income for workers, that is, $n_u^I p_u^I q_u^I = w_u\lambda$. When all firms are concentrated in the urban area, the equilibrium urban wage w_u^* is thus obtained:

$$w_u^* = \frac{\gamma}{(1-\gamma)\lambda} \tag{17}$$

Notice that w_u^* is not dependent on the cost of transporting goods. It varies positively with the relative size of the market for F-goods $\gamma/(1-\gamma)$ and inversely to λ (regional asymmetry of working population). If $w_u = w_u^*$, then $L_u^I = L_u$, and $L_r^I = 0$, corresponding to the absence of the I-industry in the rural setting. w_u^* is the maximum wage of the economy at equilibrium. In order to ensure that $w_u^* > 1$ (see eq. 5), it is assumed that

$\lambda < \gamma/(1-\gamma)$. In this case, agricultural activity is present in the rural region alone. This condition $\lambda < \gamma/(1-\gamma)$ is not too restrictive. If $\gamma = 0.85$ (according to the INSEE, French households spend 15 per cent of their budget on goods from agriculture or agrofood industries), the limit value of λ is 5.5. In this case, the population of the urban region cannot be more than 5.5 times higher than that of the rural region. In most OECD countries, more than 20 percent of the population lives in rural areas (OECD, 1994). For example, in Canada, France, Japan or United States, some four times more people live in predominantly urban areas than in rural areas, which is well below the threshold.

We determine the conditions, on the one hand, for F-firms to locate in rural areas, and, on the other hand, for I-firms to locate in rural areas.

3.2 Conditions of rural localization of F-industry

Let us look at the conditions of instability of total concentration of the F-industry in the urban area, that is, the conditions under which at least one F-firm will be encouraged to locate in the rural area . In this case, the firm must make a positive profit through locating in the rural area (in the urban area profits are zero). Thus, the level of supply of a good in the rural area must be lower than demand from the urban and rural areas made upon the F-firm, the candidate for relocation. This equilibrium is unstable when the level of demand in urban and rural areas for F-goods produced in the rural area is greater than the supply of F-firms (as there is a possibility of making a profit in region r). This condition is expressed from equation 3

$$q_r^F < \gamma \left[R_r^L \left(P_r^F\right)^{\sigma^F - 1} + (\tau_F)^{1-\sigma^F} R_u^L \left(P_u^F\right)^{\sigma^F - 1} \right] \left(p_r^F\right)^{-\sigma^F}$$

as $P_r^F = \tau P_u^F$ and $\gamma \left[R_u^L + R_r^L\right] = n_u^F p_u^F$ (see appendix A), giving:

$$q_r^F < \frac{R_r^L (\tau_F)^{\sigma^F - 1} + (\tau_F)^{1-\sigma^F} R_u^L}{R_r^L + R_u^L} \left(\frac{p_r^F}{p_u^F}\right)^{-\sigma^F} \qquad (18)$$

By replacing q_r^F, R_r^L and R_u^L by their expression (eq. 4 and 10) at total agglomeration equilibrium, we obtain:

$$1 < \frac{(\tau_F)^{\sigma^F-1} + (\tau_F)^{1-\sigma^F} w_u^* \lambda}{1 + w_u^* \lambda} (\tau_I)^{-\sigma^F} \Longleftrightarrow \frac{(\tau_F)^{\sigma^F-1} - (\tau_I)^{\sigma^F}}{(\tau_I)^{\sigma^F} - (\tau_F)^{1-\sigma^F}} < w_u^* \lambda \tag{19}$$

Then w_u^* can be replaced by its expression (eq. 17). Thus part of the production of F-goods is located in the rural region if:

$$\frac{\gamma}{1-\gamma} > \frac{(\tau_F)^{\sigma^F-1} - (\tau_I)^{\sigma^F}}{(\tau_I)^{\sigma^F} - (\tau_F)^{1-\sigma^F}} \Longleftrightarrow [(1-\gamma)(\tau_F)^{\sigma^F-1} + \gamma (\tau_F)^{1-\sigma^F}] < (\tau_I)^{\sigma^F} \tag{20}$$

This gives the following proposition:

Proposition 1 *If all industrial activities are concentrated in the urban region and if the cost of transporting I-goods is zero ($\tau_I = 1$), some F-firms are prompted to set up in the rural area if $\tau_F < \tau_F^*$ where*

$$\tau_F^* = \left(\frac{\gamma}{1-\gamma}\right)^{1/(\sigma^F-1)}$$

Conversely, if $\tau_F > \tau_F^*$, no F-firm will find it worth while setting up in the rural area. And, if all industrial activities are concentrated in the urban region and if transport costs for I-goods are positive ($\tau_I > 1$), some F-firms will be prompted to set up in the rural area if $\tau_F < \overline{\tau_F}$ where

$$\overline{\tau_F} = \left(\frac{(\tau_I)^{\sigma^F} + [(\tau_I)^{2\sigma^F} - 4\gamma(1-\gamma)]^{1/2}}{2(1-\gamma)}\right)^{1/(\sigma^F-1)}$$

$$\textit{with} \quad \partial\overline{\tau_F}/\partial\tau_I > 0 \quad \partial\overline{\tau_F}/\partial\gamma > 0 \quad \partial\overline{\tau_F}/\partial\sigma^F > 0$$

Conversely, if $\tau_F > \overline{\tau_F}$ there will be no rural industrialization.

Proof. Consider first the absence of transport costs for I-goods $\tau_I = 1$. From equation (20), it can be posited that $[1-\gamma)(\tau_F)^{\sigma^F-1} + \gamma(\tau_F)^{1-\sigma^F} = 1$. Multiplying both sides of the equation by $(\tau_F)^{\sigma^F-1}$ gives $(1-\gamma)(\tau_F)^{2(\sigma^F-1)} - (\tau_F)^{\sigma^F-1} + \gamma = 0$. Posit $X = (\tau_F)^{\sigma^F-1}$. A quadratic equation is to be solved. There are two solutions: $\tau_F^* = 1$ and $\tau_F^* = (\gamma/(1-\gamma))^{1/(\sigma^F-1)}$. Only the latter value is retained as it is within the defined domain as $\tau_F > 1$. Finally, if $\tau_I > 1$, from equation (20), then we posit $[1-\gamma)(\tau_F)^{\sigma^F-1} + \gamma(\tau_F)^{1-\sigma^F} = (\tau_I)^{\sigma^F}$. The result is obtained by an identical process to that presented above. ■

[insert figure 1 about here]

Consequently if the transport costs or inputs are not significant ($\tau_I = 1$), a fall in the cost of transporting F-goods may bring about the dispersion of F-firms. This result is the opposite of that reported by Krugman (1991). In our context, some F-firms no longer find it worth while remaining close to urban I-firms. This stems from the assumption that labor is immobile which induces competition on the labor market. As the cost of transporting F-goods falls, an increasing number of firms can supply the larger market (the urban region) from the rural region. Rural F-firms benefit from a lower labor cost and the gap between the level of sales of F-firms situated in the urban area and of the same firms in the rural region falls as the cost of transporting F-goods comes down. This always holds as the level of income of households in both regions does not vary as the labor supply is geographically immobile.

When the cost of transporting I-goods is positive ($\tau_I > 1$), it is the relative transport cost that is the decisive factor: the higher the cost of transporting I-goods, the greater $\overline{\tau_F}$. Thus F-firms are dispersed at higher transport costs of F-goods as the cost of transporting I-goods rises. Classically in economic geography, when the transport costs of I-goods are high, the agglomeration force arising from vertical linkages is weak. Consequently, when the transport costs of I-goods are high, F-firms have an incentive to locate in rural areas. But, if the transport cost of intermediate goods is relatively low, producers of F-goods have an incentive to stay in the urban region, near I-firms. In this case, only a low transport cost of F-goods can favor the location of F-firms in the rural region.

The result of proposition 1 also suggests that when the preference for non-agricultural goods γ is great, rural location of F-firms occurs for higher levels of transport costs for F-goods. So, a high proportion of expenditures on non-agricultural goods favors the rural location of F-firms. This result is contrary to that reported by Krugman (1991), who assumes the workforce is perfectly mobile geographically but not sectorally. Thus, the more of their budget that households devote to manufactured goods, the greater their sensitivity to access to a large number of such goods. The population therefore seeks to be where there are more firms. As firms set up in the region where there are more outlets, an agglomeration process is observed. In our case, the absence of geographic mobility of workers generates a shortage on the urban labor market as a result of increased demand for manufactured goods. Thus the larger the market for manufactured goods, the more firms there are, the greater the strain on the urban labor market, and the more industrial firms are prompted to set up in ever smaller rural areas.

Finally, our result also means that the more competitive the F-sector is, the smaller the gap between the two transport costs before F-firms disperse to the rural area. Increased competition on the market for goods σ^F therefore prompts dispersion of the F-industry. This result is consistent with that classically found in economic geography.

We have seen the conditions on which F-firms relocate in the rural area given that all I-firms are located in the urban area. In the next part, the same procedure is applied for I-goods.

3.3 Conditions of rural localization of I-industry

We turn now to the I-sector. The reasoning is similar to what has gone before. The F-industry is concentrated entirely in the urban area ($n_r^F = 0$, $R_r^F = 0$). We determine from what level of transport costs I-firms set up in the rural area. To that end, we need to determine an urban wage level w_u' above which at least one I-firm situated in the urban area is prompted to relocate to the rural area. We reason along the same lines as in the previous subsection. Location of an I-firm in the rural region is profitable if:

$$
\begin{aligned}
q_r^I &< \left[R_r^F\left(P_r^I\right)^{\sigma^I-1}+(\tau_I)^{1-\sigma^I}R_u^F\left(P_u^I\right)^{\sigma^I-1}\right]\left(p_r^I\right)^{-\sigma^I} \\
\Leftrightarrow &\; q_r^I < \frac{R_r^F\left(\tau_I\right)^{\sigma^I-1}+(\tau_I)^{1-\sigma^I}R_u^F}{R_r^F+R_u^F}\left(\frac{p_r^I}{p_u^I}\right)^{-\sigma^I} \\
\Leftrightarrow &\; 1<(w_u)^{\sigma^I}\left(\tau_I\right)^{1-\sigma^I}
\end{aligned}
\tag{21}
$$

That is, I-firms have an incentive to locate in the rural region if $w_u > (\tau_I)^{(\sigma^I-1)/\sigma^I}$. We define $w_u' = (\tau_I)^{(\sigma^I-1)/\sigma^I}$, the urban wage allowing zero profit whatever the location. If the urban wage when all industrial activity is concentrated in the large region, w_u^* (eq. 17), is lower than the threshold wage w_u' which allows dispersion, dispersion never occurs. This condition may be written, replacing w_u^* and w_u' by their expression:

$$
(\tau_I)^{(\sigma^I-1)/\sigma^I} > \frac{\gamma}{(1-\gamma)\lambda}
$$

Otherwise, some of the I-firms become located in the rural region. So, if w_u^* is higher (lower) than w_u', profits are negative (positive) and firms are prompted to move (stay). This leads to the following proposition:

Proposition 2 *When all industrial activities are located in the urban region, I-firms relocate to the rural area if $\tau_I < \overline{\tau_I}$ where*

$$
\begin{aligned}
\overline{\tau_I} &= \left(\frac{\gamma}{(1-\gamma)\lambda}\right)^{\frac{\sigma^I}{\sigma^I-1}} \\
\partial\overline{\tau_I}/\partial\sigma^I &> 0 \quad \partial\overline{\tau_I}/\partial\lambda < 0 \quad \partial\overline{\tau_I}/\partial\gamma > 0
\end{aligned}
$$

Otherwise the rural area is devoted exclusively to agriculture.

[Insert figure 2 about here]

It can be seen that dispersion occurs only when transport costs of I-goods are low enough. This is the opposite result to that reported by Walz (1996b), which shows that, in a growth model, the reduction in transport costs for intermediate manufactures promotes agglomeration of activity. In our case, the advantage of being situated close to the lower cost production factors outweighs the advantage of proximity to demand for input. Moreover, as before, the incentive to set up in rural areas increases with the level of competition in the I-sector (σ^I) and with the preference for manufactures γ. These findings are similar to those reported by Venables (1996) from simulation.

Our result also highlights another condition for rural industrialization. An increase in the population gap between the two regions λ reduces the transport cost below which activities are dispersed in the rural region because the agglomeration force (arising from market size effect) is stronger. If inequalities in terms of population size are too high between regions, industrial activity will not set up in the rural area. If this gap is high enough, that is, $\lambda > \gamma/(1-\gamma)$, then the I-industry remains in the urban area alone (because then $\overline{\tau_I} < 1$). However, if $\lambda < \gamma/(1-\gamma)$, then some production may be relocated in the rural area. Similarly, if the relative size of the market for F-goods $\gamma/(1-\gamma)$ is large enough, some industrial production may relocate in the rural area.

This subsection has set out the conditions for an I-firm to set up in the rural region given that all F-firms are situated in the urban region. The same approach was adopted in the previous subsection for the F-industry. In the next section we combine the two approaches to find the conditions for rural industrialization depending on the relative values of transport costs.

4. Conditions for rural industrialization

In this section, we determine the condition for achieving rural industrialization whichever the type of industry, by crossing the two conditions studied in the last section. In this context, we study the consequences for rural industrialization of a fall in the cost of transporting F- (I-) goods for a given cost of transporting I- (F-) goods. Combining propositions 1 and 2 gives the conditions for rural industrialization whichever the sector, that is:

Proposition 3 *At least one I- or F-firm will relocate in the rural area if* $\tau_F < \overline{\tau_F}$ *or* $\tau_I < \overline{\tau_I}$ *with*

$$\overline{\tau_F} = \left(\frac{(\tau_I)^{\sigma^F} + [(\tau_I)^{2\sigma^F} - 4\gamma(1-\gamma)]^{1/2}}{2(1-\gamma)} \right)^{1/(\sigma^F - 1)}$$

$$\overline{\tau_I} = \left(\frac{\gamma}{(1-\gamma)\lambda} \right)^{\frac{\sigma^I}{\sigma^I - 1}}$$

[insert figure 3 about here]

Figure 3 shows the areas of dispersion and agglomeration depending on relative transport costs. Let us analyze the result considering first that the value of transport costs of F-goods is given. There are three possible cases depending on the level of transport costs for F-goods:

(i) For relatively high transport costs of F-goods ($\tau_F > \overline{\tau_F}[\overline{\tau_I}]$) an inverse U relationship holds between the fall in transport costs of intermediate manufactures and the degree of spatial concentration. When the transport cost of I-goods is high, some of the firms producing F-goods are prompted to relocate to the rural region. When the costs of transporting I-goods take values mid-way along the scale, industrial firms are all prompted to cluster in the urban region. Finally, when transport costs for I-goods are low enough, some of the I-firms are prompted to relocate.

Under certain circumstances then we obtain the inverted U-shaped relationship between a fall in transport costs and regional inequalities emphasized by Krugman and Venables (1995) who do not explicitly distinguish between F- and I-sectors. The relationship is made possible first of all by the fall in transport costs for I-goods. This inverted U relationship is also determined by the sufficiently high cost of transporting F-goods. Moreover, when the cost of transporting I-goods is high, geographical proximity to final demand is an explicit dispersion factor in our case (F-firms relocate). Likewise, when trade costs take intermediate values, it explicitly appears that firms concentrate within one region so as to take advantage of the returns to scale related to input-output relationships. Finally, it appears clearly that when trade costs of manufactures are low, some firms find it worth while relocating because of labor market pressures (I-firms relocate).

(*ii*) For intermediate values of transport costs of F-goods, that is $\tau_F^* > \tau_F > \overline{\tau_F}[\overline{\tau_I}]$, there are two modifications compared with the previous situation. Total agglomeration does not occur. Moreover, when the cost of transporting I-goods is low enough, both F- and I-firms are prompted to relocate in the rural area.

Consequently, where transport costs for F-goods are not high enough, there is no longer an inverted U relationship between the fall in transport costs and the degree of agglomeration. In this case, F-firms may serve the urban area from the rural area taking with them I-firms when the transport cost of I-goods takes medium values. In this latter case, the geographic proximity of supply and demand for inputs is preferable. Where transport costs for F-goods take mean values, a U shaped relationship can be observed between the cost of transporting I-goods and the degree of agglomeration. When these costs are high, only F-firms are prompted to relocate, then when they fall, both F- and I-firms relocate, and finally at low levels only I-firms are prompted to relocate.

(*iii*) For low transport costs of F-goods, $\tau_F < \tau_F^*$, a monotonic relationship is observed. F-firms are first prompted to relocate and then when transport costs of I-goods fall, I-firms are also prompted to relocate in the rural area. Transport costs become so low that the costs of relocation in the rural area, caused by the fall in demand for goods from the urban region, are low compared with the gains from escaping competition on the urban market for goods (for F-firms) and on the urban labor market (for I-firms).

Let us now analyze the effect of a reduction in transport costs for F-goods for given values of transport costs for I-goods. If these transport costs for I-goods are relatively low ($\tau_I < \overline{\tau_I}$) then industrial activities remain in rural areas, whatever the transport cost of F-goods. If the transport costs of I-goods are high ($\tau_I > \overline{\tau_I}$) then a fall in the cost of transporting F-goods prompts F-firms to disperse while I-firms remain in the urban region. When the cost of transporting I-goods is high enough, some of the F-firms relocate in rural areas to be closer to rural households. The lower the cost of transporting F-goods, the more the reduced demand from urban areas due the relocation is offset by the increase in rural demand.

The results obtained determine the conditions under which some of the firms in the industrial sector will relocate in the rural area, given that all of the firms of the other sector remain in the urban area. However, induction effects may occur. Firms of one sector may relocate taking with them some of the firms from the other sector. The next section looks at such induction effects.

5. Induction effects and rural sectoral structure

From propositions 1, 2, and 3 we only know the sectoral structure of the rural region in two cases. Indeed, if $\tau_I > \overline{\tau_I}$ and $\tau_F > \overline{\tau_F}$ then the rural area is made up solely of an agricultural sector. And if $\tau_I < \overline{\tau_I}$ and $\tau_F < \overline{\tau_F}$, then the rural area is composed of three sectors. But, there exist two cases where we do not know the rural sectoral structure:

(i) If $\tau_I < \overline{\tau_I}$ and $\tau_F > \overline{\tau_F}$ then the agricultural sector and the I-sector are present in the rural area while the F-sector is confined to the urban region (case 1). However, it may be that once the I-firms have relocated in the rural area, F-firms may in turn be prompted to relocate there.

(*ii*) Likewise, we do not know if the I-firms are prompted to set up in the rural region when $\tau_I > \overline{\tau_I}$ and $\tau_F < \overline{\tau_F}$, conditions under which we know that at least one F-firm is observed in the rural region (case 2).

We therefore seek to analyze the presence of any induction effects. To do this we must determine whether the total agglomeration of F-firms is unstable when the I-industry is found in both regions. We determine therefore the industrial structures of the rural region in the case where $\tau_I > \overline{\tau_I}$ and $\tau_F < \overline{\tau_F}$ (case 2) and where $\tau_I < \overline{\tau_I}$ and $\tau_F > \overline{\tau_F}$ (case 1). Let us begin with the latter case where $\tau_I < \overline{\tau_I}$ and $\tau_F > \overline{\tau_F}$.

Case 1. We determine whether the total agglomeration of F-firms is unstable when the firms are spread between the two regions. To do this, let us divide up equation (19). By this arrangement, some of the F-firms relocate in the rural region if:

$$\frac{(\tau_F)^{\sigma^F-1} - (\tau_I)^{\sigma^F}}{(\tau_I)^{\sigma^F} - (\tau_F)^{1-\sigma^F}} < w_u \lambda \tag{22}$$

In the present case, w_u is between 1 and $\gamma/[(1-\gamma)\lambda]$. The right-hand side of the equation (22) is smaller than that of equation (19). Consequently, as the left-hand sides of both equations are the same, we can conclude that the incentive for F-firms to relocate is less than in the case where I-firms are present in both regions than in the case where I-firms are agglomerated in the urban region. Indeed, in this instance, with a given price index for F-goods, the level of final demand from the urban region falls as the income of urban workers falls when the I-industry is dispersed. Thus, F-firms find it worth while remaining agglomerated so as to reduce the price index level (eq. 2) to maintain a high level of final demand (eq. 3). This implies therefore that if $\tau_I < \overline{\tau_I}$ and $\tau_F > \overline{\tau_F}$, then the rural area is composed of an agricultural sector and an I-sector (see Figure 4).

[Insert figure 4 about here]

However, this result is obtained for a total number of F-firms fixed ex ante corresponding to the number of firms when all the F-industry is agglomerated in the urban area. Now the total number of firms for the sector is not exogenous, contrary to the model of Krugman (1991). Indeed, this number varies with the values of the parameters of the economy. It may be therefore that the number of F-firms is greater when $\tau_I < \overline{\tau_I}$ and $\tau_F > \overline{\tau_F}$ than in the case of complete agglomeration. The results are therefore dependent on the assumption that the number of F-firms is less than or equal to the total number of firms when all F-industry is agglomerated in the urban area, denoted $\overline{n}^F$. Above this limit ($\overline{n}^F$), supplementary analyses must be made to investigate the local sectoral structure. This is beyond the scope of this paper. The value of the limit is determined in Appendix A.

Case 2. Where $\tau_I > \overline{\tau_I}$ and $\tau_F < \overline{\tau_F}$, it can be shown that the I-industry will not find it worth while dispersing when the F-industry is situated in both regions. To prove this, we proceed as in paragraph 4.3. Taking equation (21) given now that $R_r^F > 0$ and positing

$$f = R_u^F/(R_r^F + R_u^F),$$

we get:

$$(w_u')^{-\sigma^I} < (1-f)(\tau_I)^{\sigma^I - 1} + f(\tau_I)^{1-\sigma^I}$$

In the case of agglomeration of F-firms, we have $R_r^F = 0$ and consequently $(w_u')^{-\sigma^I} < (\tau_I)^{1-\sigma^I}$. As the left-hand sides of the last two equations are identical, the incentive for I-firms to disperse when the F-industry is dispersed is greater than when F-firms are fully agglomerated if:

$$(\tau_I)^{1-\sigma^I} < (1-f)(\tau_I)^{\sigma^I - 1} + f(\tau_I)^{1-\sigma^I}$$

This equation invariably obtains as $\tau_I > 1$ and $\sigma^I > 1$. Consequently, in this case, there is an induction effect because the dispersion of F-firms drives the dispersion of I-firms. In this case, I-firms have identical labor costs whatever the location of the F-industry. Consequently when some F-firms relocate to the rural area, outlets for I-firms fall if they all remain in the urban region. Proximity of demand for inputs therefore favors dispersal of I-firms. As before, this result is obtained for a number of I-firms fixed corresponding to the number of firms when the entire I-industry is concentrated in the urban area. Now the total number of I-firms is endogenous because of the sectoral mobility of labor. The number of I-firms when all are located in the urban area, $\overline{n}^I$, is calculated in Appendix B.

The following proposition summarizes the foregoing results:

Proposition 4 *The sectorial structures of the rural area are based on the relative values of transport costs of F- and I-goods depending on the following modalities: (i) if* $\tau_I > \overline{\tau_I}$ *and* $\tau_F > \overline{\tau_F}$*, the less populous region accommodates the agricultural sector only. (ii) if* $\tau_I < \overline{\tau_I}$ *and* $\tau_F < \overline{\tau_F}$*, the less populous region is endowed with all sectors of activity, that is, agriculture, F-industry, and I-industry. (iii) if* $\tau_I < \overline{\tau_I}$ *and* $\tau_F > \overline{\tau_F}$*, and if* $n^F \leq \overline{n}^F$*, the less populous region is composed of agricultural and I-industry sectors. (iv) if* $\tau_I > \overline{\tau_I}$ *and* $\tau_F < \overline{\tau_F}$*, and if* $n^I \leq \overline{n}^I$*, then the less populous region is composed of an agricultural sector, F-industry, and I-industry. The limits are defined by:*

$$\overline{n}^I = \frac{\lambda}{\alpha^I \sigma^I}$$

$$\overline{n}^F = \tau_I \left(\gamma + \gamma\lambda(\tau_I)^{\sigma^I/(\sigma^I-1)}\right)^{\sigma^I/(\sigma^I-1)}$$

Recall that cases (*iii*) and (*iv*) of proposition 4 are confirmed for a number of industrial firms fixed corresponding to the total agglomeration of I- and F-firms in the urban region. It may be therefore that the number of F- or I-firms is greater when $\tau_I < \overline{\tau_I}$ and $\tau_F > \overline{\tau_F}$ or $\tau_I > \overline{\tau_I}$ and $\tau_F < \overline{\tau_F}$. Figure 4 summarizes proposition 4.

6. Conclusion

The aim of this paper is to account for industry remaining in rural areas and even its increased presence there despite falls in transport costs of goods. We have shown through a general equilibrium model that the relative value of transport costs (and not their absolute value) is a strategic variable for location decisions.

It is shown for example that there is a U relationship between the fall in transport costs for I-goods and the share of I- or F-firms in rural region, which is valid only for relatively high costs of transporting F-goods. A reduction in the transport costs of intermediate goods encourages the dispersion of firms if the transport cost of final goods is high enough. When transport costs of F-goods are relatively high, the F-firms locate near final demand, which is spatially dispersed. And, when transport costs of I-goods are relatively low, the I-firms locate near F-firms, which, in this case, are spatially dispersed. Therefore, if the transport cost of intermediate goods is relatively low, some of producers of final and intermediate goods have an incentive to locate in rural areas.

Analysis has also confirmed the idea that the presence of industry in rural environments may be independent of the agricultural sector. Moreover, the relative values of transport costs for I- and F-goods required for observing rural industrialization emphasize other variables such as the relative size of the market for F-goods and the level of competition on the market for goods.

The results obtained are also part of the debate about the contrasted effects on the location of industry of reduced transport costs brought about by regional transport infrastructure policy (Martin and Rogers, 1995). Nonetheless, the analysis of spatial configurations of equilibrium and welfare depending on the relative values of transport costs has not been analyzed. We therefore stop short of drawing conclusions in terms of development policies. That task deserves specific attention.

References

Bryden J., Bollman R. (2000) Rural employment in industrialised countries. Agricultural Economics 22:185-197.

Champion A. (1998) Studying counterurbanization and the rural population turnaround. In: Boyle P., Halfacree K. (eds) Migration into rural areas: theories and issues. Wiley, Chichester.

Combes P.-Ph., Lafourcade M. (2001) Transportation costs decline and regional employment inequalities: Evidence from France, 1978-1993. Working Paper CERAS 01-01.

Decressin J., Fatas A. (1995) Regional labor market dynamics in Europe. European Economic Review 39:1627-1655.

De Palma A., Ginsburgh V., Papageorgiou Y., Thisse T. (1985) The principle of minimum differentiation holds under sufficiant heterogeneity. Econometrica 53:767-781.

Doeringer P. (1984) Internal labor markets and paternalism in rural areas. In Osterman P. (ed) Internal labor markets. MIT Press, 271-289.

Dixit A., Stiglitz J. (1977) Monopolistic competition and optimum product diversity. American Economic Review 67:297-308.

Faini R. (1999) European migrants: an endangered species? In Baldwin R., Cohen D., Sapir A., Venables A. (eds.) Market integration regionalism and the global economy. Cambridge University Press, 228-253.

Fujita M., Krugman P. (1995) When is economy monocentric? von Thünen and Chamberlin unified. Regional Science and Urban Economics 25:505-528.

Fujita M., Hamaguchi N. (2001) Intermediate goods and the spatial structure of an economy. Regional Science and Urban Economics 31 79-109.

Goffette-Nagot F., Schmitt B. (1999). Agglomeration economies and spatial configuration in rural areas. Environment and Planning A 31:1239-1257.

Greenwood M. (1997) Internal Migration in developed countries. In Rosenweig M.,Stark O. (eds) Handbook of population and family economics. Amsterdam Elsevier, 647-720.

Kilkenny M. (1998) Transport costs and rural development. Journal of Regional Science 38:293-312.

Krugman P. (1991) Increasing returns and economic geography. Journal of Political Economy 99:483-499.

Krugman P., Venables A. (1995) Globalization and the inequality of nations. Quarterly Journal of Economics 110:857-880.

Laundhart W. (1882) Die bestimmung des zwekmässigsten standortes einer gewerblichen anlage. Zeitschrift des Veriens Deutscher Ingenieure 26:106-115.

OECD (1994). Creating rural indicators for shaping territorial policy. Paris: OECD.

Ottaviano G., Puga P. (1998) Agglomeration in the global economy: A survey of the 'new economic geography'. The World Economy 21:707-731.

Samuelson P. (1954) The transfer problem and transport costs II : Analysis of trade impediments. Economic Journal 53:202-211.

Venables A. (1996) Equilibrum locations of vertically linked industries. International Economic Review 37:341-359.

Walz U. (1996a) Long-run effects of regional policy in an economic union. Annals of Regional Science 30:165-183.

Walz U. (1996b) Transport costs, intermediate goods and localized growth. Regional Science and Urban Economics 26:671-695.

Appendix A. Relation between workers' income and F-Firms' income

If all I- and F-firms are in the urban area, that is, $n_r^F = 0$ and $P_r^F = \tau_F P_u^F$, then the equilibrium relation on the market for F-goods (eq. 3) is written

$$\begin{aligned} q_u^F &= \gamma\left[R_u^L\left(P_u^F\right)^{\sigma^F-1} + (\tau_F)^{1-\sigma^F} R_r^L\left(P_r^F\right)^{\sigma^F-1}\right]\left(p_u^F\right)^{-\sigma^F} \\ &\Leftrightarrow \ 1 = \gamma\left[R_u^L + R_r^L\right]/n_u^F p_u^F. \end{aligned}$$

This gives the relationship $\gamma\left[R_u^L + R_r^L\right] = n_u^F p_u^F$.

Appendix B Number of industrial firms at total agglomeration equilibrium

First we calculate the number of I-firms at total agglomeration equilibrium. Let $\overline{n}^I$ be the total number of I-firms fixed ex ante when all I-industry is agglomerated in the urban area. From equations (13), (14) and (15) we obtain the limit value:

$$\overline{n}^I = \overline{n}_u^I = \frac{L_u^I}{\alpha^I \sigma^I} = \frac{\lambda}{\alpha^I \sigma^I}$$

We then determine the total number of firms when all F-industry is agglomerated in the urban area, denoted $\gamma\left[R_u^L + R_r^L\right] = n_u^F p_u^F$. We therefore have $n_r^F = 0$. n_u^F is determined from the equilibrium on the market of outputs:

$$q_u^F = \gamma\left[R_u^L\left(P_u^F\right)^{\sigma^F-1} + (\tau_F)^{1-\sigma^F} R_r^L\left(P_r^F\right)^{\sigma^F-1}\right]\left(p_u^F\right)^{-\sigma^F}$$

As $P_r^F = \tau_F P_u^F$, we get: $\gamma\left[R_u^L + R_r^L\right] = n_u^F p_u^F$ and consequently

$$\overline{n}_u^F = \gamma(1 + w_u\lambda)[(\sigma^F - 1)/(\sigma^F \beta^F P_u^I)$$

We must then determine w_u and P_u^I. The urban wage w_u is determined from market equilibria of I-goods, that is, $q_u^I = R_u^F\left(P_u^I\right)^{\sigma^I-1}(p_u^I)^{-\sigma^I}$ and $q_r^I = (\tau_I)^{1-\sigma^I} R_r^F\left(P_u^I\right)^{\sigma^I-1}(p_r^I)^{-\sigma^I}$. As $q_r^I = q_u^I$, it can be inferred that $w_u = (\tau_I)^{\sigma^I/(\sigma^I-1)}$. The price index of I-goods P_u^I is expressed as: $P_u^I = \left(n_u^I \left(p_u^I\right)^{1-\sigma^I} + \left(\tau^I\right)^{1-\sigma^I} n_r^I \left(p_r^I\right)^{1-\sigma^I}\right)^{\frac{1}{1-\sigma^I}}$. Replacing n_u^I and p_u^I by their expressions, we get

$$P_u^I = \left(\frac{\lambda}{\alpha^I \sigma^I}\right)^{1/(1-\sigma^I)} \frac{\sigma^I \beta^I}{\sigma^I - 1} [\lambda \left(\tau_I\right)^{-\sigma^I} + \left(\tau^I\right)^{1-\sigma^I} L_r^I]^{\frac{1}{1-\sigma^I}}$$

where $L_r^I = 1 - (1-\gamma)(1 + \lambda \left(\tau_I\right)^{\sigma^I/(\sigma^I-1)}$. With simplifications $\beta^F = (\sigma^F - 1)/(\sigma^F)$, $\alpha^F = 1/\sigma^F$, $\beta^I = (\sigma^I - 1)/(\sigma^I)$, and $\alpha^I = 1/\sigma^I$, it can be deduced that the limit value of the total number of F-firms is:

$$\overline{n}^F = \overline{n}_u^F = \tau_I \left(\gamma + \gamma\lambda(\tau_I)^{\sigma^I/(\sigma^I-1)}\right)^{\sigma^I/(\sigma^I-1)}$$

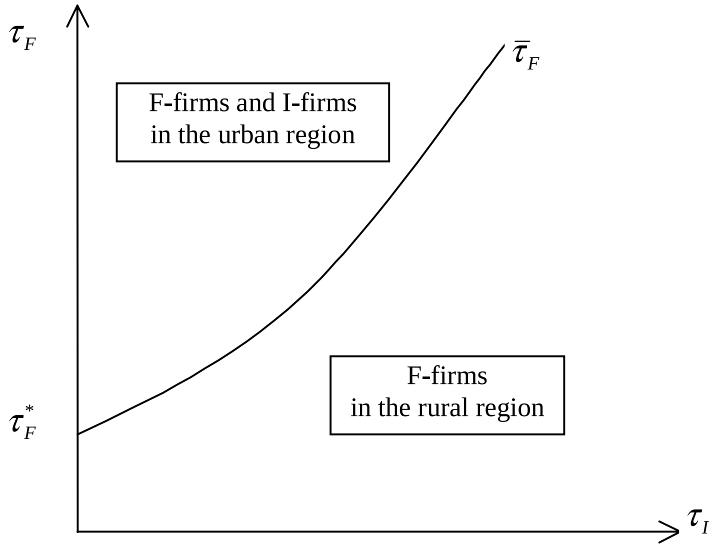

Figure 1: Conditions of rural localization of F-industry

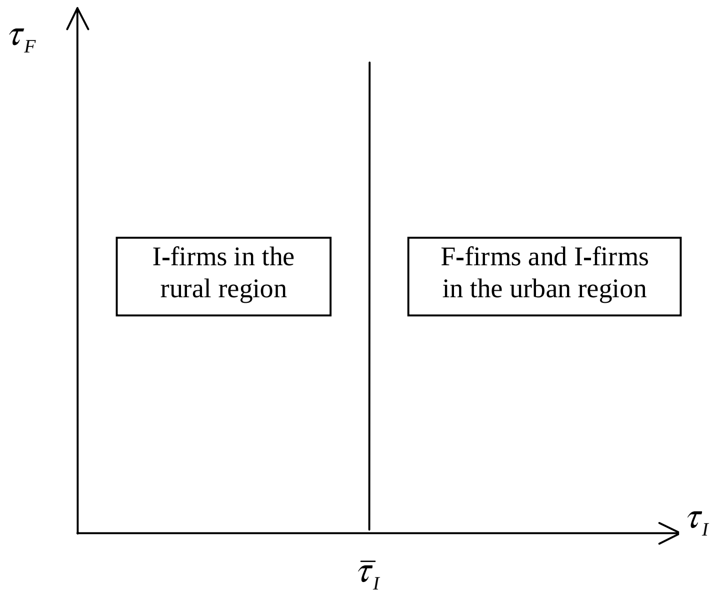

Figure 2: Conditions of rural location of I-industry

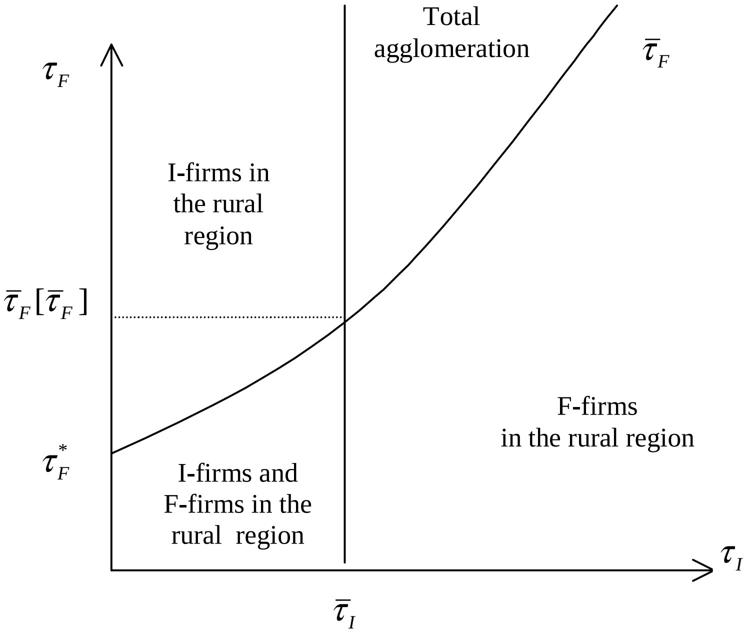

Figure 3: Conditions for rural industrialization

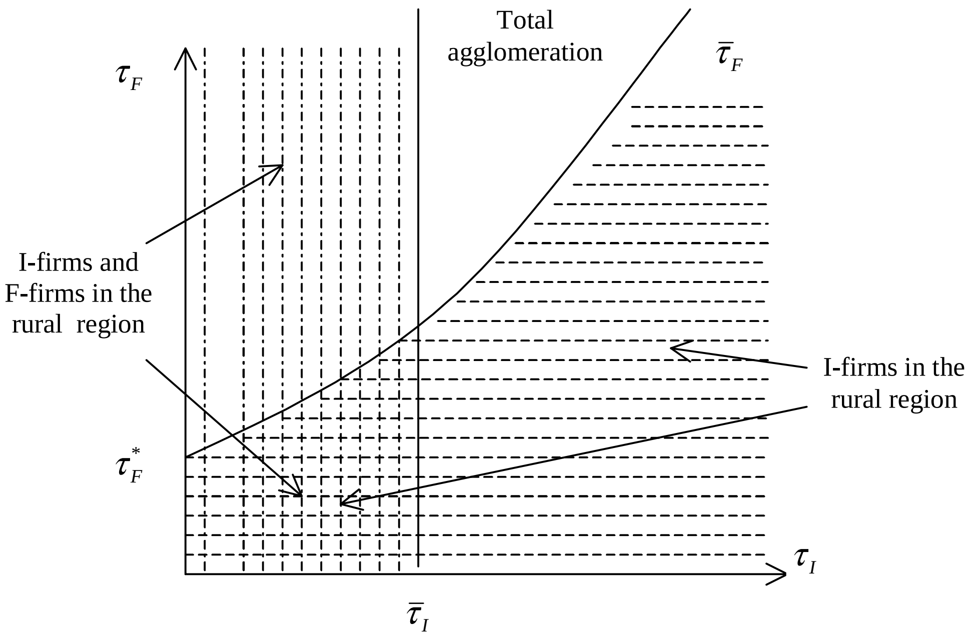

Figure 4: Sectoral rural structures for $n_I \leq \overline{n}^I$ and $n_F \leq \overline{n}^F$