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Research Article

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Posted Date: June 8th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-596085/v1>

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Impacts of Public Telecommunications Policy on Industrial Geography and Welfare

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Abstract:

We include a clear distinction between transport and telecommunication infrastructures. We assume that public expenditure enables Information Technology Enabled Services to be traded abroad without the use of traditional transport modes. We show that the increase in the knowledge spillovers mainly related to mobile human capital and trade of services can develop industrialization in developing country, leading to less spatial inequalities. This latter must invest more in telecommunication than in transportation infrastructures to attract both industrial and knowledge activities. The welfare level will be improved for skilled workers in both countries when public policy decreases the cost of trading knowledge.

Keywords:

Knowledge Spillovers; ITES; Public Policy; Repartition of Activities; Welfare

JEL:

H76; O30; R38; R12; D62

Funding:

This work was supported by the Dean of Scientific Research (DSR) of King Abdulaziz University under Grant number G: 169-120-1439

1. Introduction

Efficient access to telecommunication infrastructure contributes to faster growth, better economic performance and improved welfare (Martin 1999; Roller and Waverman 2001; Riou 2003). This enables firms to access knowledge and information, reduce transaction costs (Joshi 2009), and profit from technological opportunities (Fink et al. 2005; Tang 2006). In addition to promoting development, telecommunication infrastructure provides several opportunities for the export of technology-intensive services from developing to developed countries (ODI 2008; World Bank 2016). In fact, they can create new export frontiers for developing and emerging countries, which are traditionally constrained by high transport costs (Freund and Weinhold, 2002; Grossman and Rossi-Hansberg 2008). Consequently, public telecommunication policy is essential to promote the knowledge spillovers, thus reducing spatial inequalities (Riou 2003; Montmartin 2013). This paper introduces a clear distinction between two kinds of infrastructures to investigate how public telecommunication policy can influence location and welfare.

Despite the importance of public policy in reducing the transaction costs on knowledge flows and goods across countries, very few studies have attempted to determine their potential effects on industrial geography and household welfare. In the literature, some works focused on Krugman's seminal model (Krugman 1991) have extended its original framework to provide new insights on the study of economic spatial inequalities. Baldwin and Martin (2004) and Fujita and Thisse (2002, 2013) developed mixed models shared by both New Economic Geography (NEG) and endogenous growth theories. These authors showed that the growth rate of global economy is mainly related to the spatial repartition of an innovation sector across regions. Their conclusions confirm the existence of trade-off between efficiency and spatial equity (Gaspar 2018). In terms of public policy, there is a conflict between social cohesion and economic growth.

With the assumptions that knowledge spillovers are imperfectly diffused between regions (Baldwin, Martin and Ottaviano 2001; Riou 2003), Maurseth and Verspagen (1999) found that the imperfect repartition of innovative activities over Europe is clear in the North-South context, with high innovation activity in the North and low activity in the South. Even at the interregional levels, the knowledge concentration persists. Baldwin, Martin and Ottaviano (2001) introduced the concept of imperfect interregional spillovers in an economic geography and growth model. The better diffusion of knowledge across regions is able to make core-periphery equilibrium instable.

According to Martin (1999), public policy consisting to decrease innovation cost can support economic growth and reduce the regional disparities, whereby improved diffusion of knowledge is able to increase the productivity of R&D, and therefore to decrease the relocation cost of firms. Using a similar framework of Martin and Ottaviano (1999), Riou (2003) introduced imperfect interregional spillovers in R&D to investigate whether a repartition of technological interactions can induce more growth and less spatial inequalities. By introducing two interregional infrastructures (e.g. transportation and telecommunication), he supposed that transportation infrastructure can be used for both transporting goods and knowledge. In terms of public policy, he found that any increase in the interregional spillovers may accelerate the convergence in industrial

geography. The gains of agglomeration also can decrease according to the quality of telecommunication infrastructure.

In the same line, Montmartin (2013) employed a model of NEG and endogenous growth similar to Martin and Ottaviano (1999). Unlike technological externalities that are supposed to be perfectly mobile between countries, labor can be employed in all sectors of the economy, and is mobile only between sectors, within each country. In this model, the author showed that a better diffusion of knowledge between regions is necessary for increasing the productivity of R&D and reducing the cost of relocation of industrial firms. Indeed, it will be more profitable for the EU, before subsidizing R&D activities, to improve conditions for knowledge transfer between European countries. The author also highlighted the importance of improving telecommunication networks and the mobility of workers in the economy.

Our study is an extension of Krugman and Venables (1995) and Martin and Rogers (1995). With the introduction of different quality level in infrastructures, we investigate whether public telecommunication policy by decreasing transactions costs of trading ITES may reduce inequalities between countries, whereby accelerating convergence in industrial geography and welfare. We analyze which public spending in infrastructures can be privileged in this context. The role of public expenditure will be incorporated following the work of Martin and Rogers (1995) and Chatti et al. (2019).

The only existence of localized technological spillovers can explain the amplification of agglomeration and spatial disparities phenomenon (Marshall 1926). This is due especially to the fact that firms which are located in the favored region can profit, through social interaction, from a higher level of technological knowledge and innovation (Baldwin, Martin and Ottaviano 2001). Therefore, public policy whose objective is to minimize regional inequalities can be very different in this purpose. Martin (1999), Riou (2003) and Montmartin (2013) underlined the fact that reducing transaction costs on the trading of ideas is better than reducing transaction costs on trade in goods. In addition, Martin (2002) suggested that rather than spending in transport infrastructures (e.g. highways, road and rail networks), it will be crucial to accelerate the technological convergence between regions. Baldwin, Martin and Ottaviano (2001) and Riou (2003) incorporated imperfect interregional spillovers in a mixed NEG and growth model. They broadly show that the increase of diffusion of ideas is able to reduce inequalities between regions.

We introduce two kinds of infrastructures in order to improve both trading of goods and knowledge: the telecommunication and transport. While transport infrastructure is devoted to support trading of goods, telecommunication infrastructure is devoted to facilitate the trading of ITES across countries. This choice is due to the fact that previous works suggested that transport infrastructure can be used not only for the trade of goods but also for the trade of knowledge at the same time (Baldwin, Martin and Ottaviano 2001; Baldwin, Forslid, Martin, Ottaviano and Robert-Nicoud 2003; Riou 2003). Therefore, we propose an original contribution in this purpose.

First, we assume that knowledge transfer mainly related to the trading of ITES and the mobility of human capital (Gaspar and Glaeser 1998) can be improved using public telecommunication infrastructure. Indeed, the existence of high-skilled workers in some developing and emerging countries may open-up new opportunities of service export using telecommunications (Nasir and Kalirajan, 2016). The diffusion of knowledge between firms also depends on the labor mobility since a part of the knowledge flows is tacit which requires more physical interactions (Gaspar and Glaeser 1998). Second, we suppose that the flows of goods can be increased when public policy improves the quality of transportation like Martin and Rogers (1995). Moreover, we suppose that the intensity of the flows of knowledge depends on the quality of telecommunications. We display the fact that public spending in telecommunications can accelerate relocation of firms in developing country; thus, reducing spatial inequalities. Finally, we show the positive effect of spending in telecommunications on household welfare.

This paper is in five sections. Section 2 presents the NEG model and derives the short-run equilibrium conditions. Section 3 analyses the stability conditions in relation to spending in infrastructures, and the equilibrium location of firms. Section 4 presents a welfare analysis. Section 5 concludes the study and offers some recommendations.

2. The Model

The general framework is an extension of Krugman and Venables (1995) and Martin and Rogers (1995). In this model, we shed light on the role of public telecommunication policies in generating more knowledge flows and therefore, more spatial distribution of incomes and productive activities. We assume the existence of two countries that trade with each other, North (N) and South (S), which are perfectly identical in size, preferences and technology, except for their initial quality levels of infrastructures (Takahashi, 2011). In each economy, we consider the existence of three private sectors and a public sector, four goods and three factors of production.

2.1. Assumptions

Consumers maximize their utility by choosing between two final goods: homogeneous and manufacturing goods. They have access to the homogeneous product that is produced by the agricultural sector with constant returns to scale. In addition, they prefer manufacturing varieties that can be exported abroad with an *iceberg* transportation cost. We use the Dixit-Stiglitz monopolistic competition model (Dixit and Stiglitz 1977), which considers a large number of symmetric products. Each producer acts as a profit-maximizing monopolist, but free-entry drives profit to zero. Consumers have the same preferences in both countries and a Cobb-Douglas preference function over homogeneous product (the *numeraire*) and the CES aggregate of the N manufactured goods.

$$U = A^{1-\mu} M^{\mu} \quad \text{with} \quad M = \left[\sum_{i=1}^N q_i^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}, \quad 0 < \mu < 1, \quad \sigma > 1 \quad (1)$$

where A is the quantity of homogenous product consumed, M is the global quantity of manufactured goods consumed, q_i is the quantity of each variety i consumed, μ is the substitution elasticity between manufactured goods and the product tied to the land, and σ is the elasticity of substitution between different manufactured goods.

The manufacturing sector produces a number of varieties of differentiated products that are aggregated using a CES sub utility function into a composite good. The price index of this manufacturing composite is P_N^I , and takes the following form:

$$P_N^I = \left[n_N^I (p_N^I)^{1-\sigma} + n_S^I (\tau_S p_S^I)^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \quad (2)$$

where p_N^I denotes the price of manufacturing variety for the North, and the index I represents the manufacturing sector. The total demand of manufacturing varieties in the same country is presented by the following expression.

$$q_N^I = \left[(P_N^I)^{\sigma-1} D_N^I + \tau_S^{1-\sigma} (P_S^I)^{\sigma-1} D_S^I \right] (p_N^I)^{-\sigma} \quad (3)$$

where D_N^I and D_S^I represent respectively the industrial expenditure for the North and the South.

We suppose that low-skilled workers can be employed in three sectors. There are two private sectors, the agricultural with employment share λ_k^A and the manufacturing sector with share λ_k^I and one public sector with share g_{τ_k} .

$$\lambda_k^A + \lambda_k^I + g_{\tau_k} = 1 \quad (4)$$

The high-skilled workers are supposed perfectly mobile internationally and are employed in the ITES sector and the provision of telecommunications infrastructure. They are the most likely to adopt new technologies and profit from additional opportunities, depending to education and income levels (Ono and Zavodny, 2007; Goldfarb and Prince, 2008). The total high-skilled labor supply λ_{Hi}^T can be presented by the following expression.

$$\lambda_N^T + \frac{g_{\tau_N}^{ICT}}{w_N^T} + \lambda_S^T + \frac{g_{\tau_S}^{ICT}}{w_S^T} = \lambda_{Hi}^T \quad (5)$$

where λ_k^T refers to the demand of ITES firms in high-skilled workers in country k , and $g_{\tau_k}^{ICT} / w_k^T$ is the labor demand necessary to provide telecommunications infrastructure in country k .

Like Krugman (1991), we assume that agriculture is perfectly competitive, and use only low-skilled workers with constant returns to scale. One unit of labor produces one unit of product, and wages are equal in both countries. We let agriculture to be the *numeraire*, and assume that it can be traded without transaction costs. The manufacturing sector uses low-skilled workers and differentiated services (ITES) in order to produce manufactured varieties. The price index of differentiated services is denoted by the index T as presented below.

$$P_N^T = \left[n_N^T (p_N^T)^{1-\xi} + n_S^T (\tau_S^{ICT} p_S^T)^{1-\xi} \right]^{\frac{1}{1-\xi}}, \xi > 1 \quad (6)$$

where τ_N^{ICT} denotes the telecommunication costs applied on the trade of ITES in the North. Telecommunications costs are supposed asymmetric and positive between countries ($\tau_N^{ICT} < \tau_S^{ICT}$). Therefore, the quality of telecommunications infrastructure in the North is better than in the South.

The demand of ITES comes from the only intermediate consumption of manufacturing firms.

$$q_N^T = \left[\alpha \left((p_N^T)^{-\xi} (P_N^T)^{\xi-1} D_N^I + (\tau_S^{ICT})^{1-\xi} (p_S^T)^{-\xi} (P_S^T)^{\xi-1} D_S^I \right) \right] \quad (7)$$

where α is a parameter between 0 and 1 indicating the share of industrial expenditure D_k^I necessary for producing ITES, which demand is exclusively from manufacturing firms. Symmetrically, $1-\alpha$ indicates the share of manufacturing labor costs.

The production of a quantity q_k^T of any ITES variety i requires a fixed and a variable quantity of qualified labor given by:

$$l_k^T = f + \beta q_k^T \quad (8)$$

where l_k^T is the quantity of qualified labor necessary to produce q_k^T units of product i in the country k . Also, f and β are the fixed and the variable cost.

Like in most models of economic geography, each producer faces an elasticity of demand equal to the elasticity of substitution, and then will charge a price that is a constant markup over the marginal cost. This equilibrium price chosen by a technological service firm is the same, independent of the destination country.

Using the normalizations $\beta = \frac{\xi-1}{\xi}$ and $f = 1/\xi$, we get the equilibrium price expression below.

$$p_k^T = w_k^T \quad (9)$$

The profit of a technological service firm i in country k takes the following form.

$$\Pi_i^T = p_k^T q_k^T - (f + \beta q_k^T) w_k^T \quad (10)$$

Given the assumption that free entry will drive profit to zero, we find the equilibrium quantity produced by each ITES firm in country k .

$$q_k^T = q = 1 \quad (11)$$

In addition, the definition of the equilibrium quantity q_k^T enables us to determine the number of ITES varieties.

$$n_k^T = \lambda_k^T \quad (12)$$

Turning to the manufacturing production function (simplified and implicitly normalized to $A_\alpha = \alpha^{-\alpha}(1-\alpha)^{\alpha-1}$), the only difference with the Krugman (1991) model consists in the fact that the production of manufacturing varieties uses low-skilled workers and intermediate ITES; moreover, the latter are incorporated in the manufacturing production function as an aggregate of varieties, like in the consumer's utility function (Ethier 1982).

$$y_k^I = A_\alpha l_i^{1-\alpha} K_i^\alpha = F_k^I + c_k^I q_k^I \quad (13)$$

where l_i and K_i indicate respectively the quantity of low-skilled labor and the quantity of ITES necessary for producing an intermediate composite good y , which will be used to produce the manufactured products. Since our model is perfectly symmetrical, we can adopt the normalization of equalizing the fixed and variable costs of production, so that $F_N^I = F_S^I = F^I$ and $c_N^I = c_S^I = c^I$, where F^I and c^I indicate the fixed and variable cost of production, respectively. K is the aggregate of m differentiated ITES used as an input.

$$K = \left[\sum_{i=1}^m q_i^T \frac{\xi-1}{\xi} \right]^{\frac{\xi}{\xi-1}}, \xi > 1$$

where q_i^T is the quantity of each ITES variety i used as an input for a manufacturing firm in country k .

The total cost function for a manufacturing firm in country k is presented by the following expression:

$$TC_k^I = (P_k^T)^\alpha (c^I q_k^I + F^I) \quad (14)$$

2.2. The Short-Run Equilibrium Conditions

Each manufacturing producer faces an elasticity of demand equal to the elasticity of substitution, and therefore will charge a price that is a constant markup over marginal cost.

$$p_k^I = \frac{\sigma}{\sigma-1} (P_k^T)^\alpha c^I \quad (15)$$

The profit in the manufacturing sector takes the following form:

$$\Pi_k^I = p_k^I q_k^I - TC_k^I \quad (16)$$

In addition, taking into account the assumption of free entry that drives profit to zero, the equilibrium quantity for a manufacturing firm in country k is given by:

$$q_k^I = (\sigma-1) \frac{F^I}{c^I} \quad (17)$$

The equilibrium quantity q_k^I is able to determine the number of manufacturing varieties. Also, we know that the value of manufacturing (technological) production is partly composed by $1-\alpha$ of payroll of this sector, as in:

$$\lambda_k^I = (1-\alpha) n_k^I p_k^I q_k^I \quad (18)$$

Therefore, we can deduce easily the number of manufacturing varieties:

$$n_k^I = \frac{\lambda_k^I}{\sigma(1-\alpha) F^I (P_k^T)^\alpha} \quad (19)$$

The technological production coming from only the qualified labor factor accounts for α in the manufacturing production. This equation allows us to understand the relationship between both sectors with increasing returns to scale. More precisely, the term in the right shows that an increase in demand for manufacturing goods will have a positive effect on the ITES sector, in which wages will increase in order to attract the necessary labor inside each country.

Given that $w_N^T \lambda_N^T + w_S^T \lambda_S^T = \alpha n_N^I p_N^I q_N^I + \alpha n_S^I p_S^I q_S^I$, by replacing equations (15), (17), and (19), we find the following expression:

$$w_N^T \lambda_N^T + w_S^T \lambda_S^T = \frac{\alpha}{1-\alpha} (\lambda_N^I + \lambda_S^I) \quad (20)$$

The total income in country k is given by the equation below:

$$R_k = 1 + \lambda_k^T w_k^T + g_{\tau_k^{ICT}} \quad (21)$$

This equation describes the total revenues in country k . It consists of immobile non-qualified workers working in three sectors (agriculture, industry, and transport), whose income is equal to unity, so that the first term. Then, skilled workers employed in the ITES sector, λ_k^T are paid a wage rate w_k^T , so that the second term. Finally, the total revenue of skilled workers employed in the provision of telecommunication is equal to public spending in telecommunication infrastructure, $g_{\tau_k^{ICT}}$.

Manufacturing expenditure constitutes a share μ of total consumption expenditure and depend on total income, thus:

$$D_k^I = \mu(1 - g_k) R_k \quad (22)$$

Using equations (2), (15), and (19), we find after simplification the price index for the manufacturing sector.

$$P_N^I = \left[\frac{\sigma^{-\sigma} (\sigma - 1)^{\sigma-1} (c^I)^{1-\sigma}}{(1-\alpha) F^I} \left(\lambda_N^I (P_N^T)^{-\alpha\sigma} + \lambda_S^I (P_S^T)^{-\alpha\sigma} \tau_S^{1-\sigma} \right) \right]^{\frac{1}{1-\sigma}} \quad (23)$$

From equations (6), (9), and (12), we can get the price index for the ITES sector.

$$P_N^T = \left[\lambda_N^T (w_N^T)^{1-\xi} + \lambda_S^T (w_S^T)^{1-\xi} (\tau_S^{ICT})^{1-\xi} \right]^{\frac{1}{1-\xi}} \quad (24)$$

Using equation (3) and replacing the equilibrium price (15), we get the implicit equations of manufacturing nominal wages.

$$F^I = \sigma^{-\sigma} (\sigma - 1)^{\sigma-1} \left[(P_N^I)^{\sigma-1} D_N^I + \tau_S^{1-\sigma} (P_S^I)^{\sigma-1} D_S^I \right] (P_N^T)^{-\alpha\sigma} (c^I)^{1-\sigma} \quad (25)$$

Similarly, using equations (7) and (9), we find the nominal wages in the ITES sector.

$$w_N^T = \left[\alpha \left(D_N^I (P_N^T)^{\xi-1} + D_S^I (P_S^T)^{\xi-1} (\tau_S^{ICT})^{1-\xi} \right) \right]^{1/\xi} \quad (26)$$

The final demand of consumers is divided between the agricultural and the manufacturing expenditures. Thus, we can deduce the expression of real wage for high-skilled worker.

$$\Omega_k^T = w_k^T (P_k^I)^{-\mu} \quad (27)$$

3. Public Policy and Industrial Location

3.1. Telecommunications and knowledge Spillovers

Some works focused on interregional or localized knowledge spillovers (Baldwin, Martin and Ottaviano 2001; Riou 2003) introduced two infrastructures whose can facilitate the trade in goods and ideas between regions. The authors assumed that the improvement in transportation infrastructure which reduces the transaction cost in goods can also reduce the transaction cost in knowledge. However, the use of the same infrastructure to support both trade in goods and knowledge appears confusing. Moreover, these studies neglected two main things in relation to the telecommunications and knowledge spillovers. First, they failed to explain how these infrastructures are provided in each economy by ignoring the public sector in their models. Second, they did not consider explicitly the role of human capital in the diffusion of knowledge spillovers between regions. In reality, the intensity of technological relations between firms depends on the mobility of high-skilled workers due to the need of face-to-face contacts and more interactions (Gaspar and Glaeser 1998).

For these reasons, we distinguish explicitly between two kinds of transactions costs: i) a transaction cost on the manufacturing goods, and ii) a transaction cost on the intermediate services (ITES) for each country. Like Martin and Rogers (1995) and Chatti et al. (2019), we interpret transport cost on goods as directly dependent on the quality of transportation infrastructures and public services in each country: τ_N is the transport cost in the North, and τ_S is the transport cost in the South. Similarly, we interpret telecommunication cost on ITES as directly dependent on the quality of telecommunications in each country: τ_N^{ICT} is the telecommunication cost in the North, and τ_S^{ICT} is the telecommunication cost in the South. While a reduction in τ_N indicates an improvement in the quality of transportation infrastructure in the North, a reduction in τ_N^{ICT} signifies an improvement in the quality of telecommunications in the same country. For example, we consider the building of a new international airport or harbor to be an improvement in the international transportation infrastructures (Martin and Rogers 1995).

Unlike several studies that considered the telecommunication infrastructure (Martin 1999; Baldwin, Martin and Ottaviano 2001, Baldwin and Forslid 2000 and Riou 2003), we introduce explicitly a public sector whose main objective is to provide those kinds of

infrastructures, using two levels of skills: the low-skilled and the high-skilled labor. To this end, we assume that new transportation and telecommunication projects can be funded by a national income tax (Barro 1990), particularly if such projects are supplied exclusively by the public authority (Martin and Rogers 1995; Chatti et al. 2019). Thus, the total budget in both countries is equal to:

$$G = g_N R_N + g_S R_S \quad (28)$$

where g_N and g_S indicate the tax rate applied by the North and the South (respectively), and R_N and R_S represent the total income in the North and the South (respectively).

This budget serves to finance transport infrastructure g_{τ_N} and telecommunication infrastructure $g_{\tau_N}^{ICT}$ in the North and transport infrastructure g_{τ_S} and telecommunication infrastructure $g_{\tau_S}^{ICT}$ in the South. The repartition function of expenditure is given by the following equation:

$$G = g_{\tau_N} + g_{\tau_N}^{ICT} + g_{\tau_S} + g_{\tau_S}^{ICT} \quad (29)$$

Every public authority is supposed to use the labor factor to provide both transportation and telecommunication infrastructures. In each country, the transportation infrastructure is supposed to be provided by low-skilled workers (cf. Chatti et al. 2019), while the telecommunication infrastructure is supposed to be provided by high-skilled workers.

The quantity of labor necessary for the provision of transportation infrastructure is equal to g_{τ_k} . The quantity of labor necessary for the provision of telecommunication is equal to $g_{\tau_k}^{ICT} / w_k^T$. Like Martin and Rogers (1995), transport and telecommunication costs are supposed decreasing functions of the quality of corresponding infrastructure.

$$\tau_k = \tau_k(g_{\tau_k}), \tau_k^{ICT} = \tau_k^{ICT}(g_{\tau_k}^{ICT} / w_k^T) \text{ with } \partial \tau_k / \partial g_{\tau_k} < 0 \text{ and } \partial \tau_k^{ICT} / \partial g_{\tau_k}^{ICT} < 0 \quad (30)$$

3.2. The Equilibrium Location of Firms

The main objective consists to show whether public policy can reduce inequalities between the North and the South. Two spatial equilibrium configurations are considered in this study: the agglomeration and the dispersion. First, we suppose that industrial and knowledge activities are fully concentrated in the North. Consequently, the South keeps only the agricultural activity. Second, we suppose that all economic activities are well distributed between both countries. Despite the fact that equations are well-defined at the short-run equilibrium, there is no analytical solution like in most models of economic geography. Consequently, some numerical simulations will be conducted in the following section.

We study also the long-run stability conditions. The relocation of a manufacturing and/or ITES firm from the North to the South is described as unstable if the profitability exceeds the unity; otherwise, it is considered stable.

3.2.1. Concentration Equilibrium

The conditions of this configuration are described in the following expression.

$$\begin{aligned} \lambda_S^I = 0, \lambda_N^I &= \frac{\mu(1-\alpha)\left((1-g_N)(1+g_{\tau_N^{ICT}}) + (1-g_S)\right)}{1-\alpha\mu(1-g_N)}, \lambda_S^T = 0, \lambda_N^T = \lambda_q^T, w_N^I = w_S^I = 1, \\ w_N^T &= \frac{\alpha\mu\left((1-g_N)(1+g_{\tau_N^{ICT}}) + (1-g_S)\right)}{\lambda_N^T(1-\alpha\mu(1-g_N))}, w_S^T = 0 \end{aligned} \quad (31)$$

By replacing the manufacturing price index in equation (3), we can get the total demand for a manufacturing variety in the North.

$$q_N^I = (p_N^I)^{-\sigma} (P_N^I)^{\sigma-1} (D_N^I + \tau_S^{1-\sigma} \tau_N^{\sigma-1} D_S^I) \quad (32)$$

The profitability expression is given by the equation below.

$$\frac{q_S^I}{q_N^I} = (\tau_N^{ICT})^{-\alpha\sigma} \left(\frac{D_S^I}{D_N^I + \tau_S^{1-\sigma} \tau_N^{\sigma-1} D_S^I} \tau_N^{\sigma-1} + \frac{D_N^I}{D_N^I + \tau_S^{1-\sigma} \tau_N^{\sigma-1} D_S^I} \tau_N^{1-\sigma} \right) \quad (33)$$

Table 1 shows the parameters values of the concentration equilibrium. Fig. 1 shows that the concentration equilibrium is instable in the North when the transport cost in the South is sufficiently high ($\tau_S = 3$), whatever the intensity of transport cost in the North. It is important to note that the relocation of an industrial firm from the North to the South is costless and profitable if the telecommunication cost is low in the North. Fig. 2 shows that the industrial agglomeration is stable if both transport and telecommunication costs become sufficiently low in the North ($\tau_N = 1.3$ and $\tau_N^{ICT} = 1.1$). Nevertheless, it becomes instable with lower telecommunication costs and higher transportation costs in the North.

Table 1: Parameters values

Parameters	α	μ	g_N	g_S	σ	τ_S	$g_{\tau_N^{ICT}}$	τ_N^{ICT}
Fig. 1	0.6	0.6	0.2	0.4	5	3	0.3	1.1
Fig. 2	0.6	0.6	0.2	0.4	5	1.3	0.3	1.1

Fig. 1: Manufacturing stability with higher transport costs in the South

$$\tau_s = 3$$

Fig. 2: Manufacturing stability with lower transport costs in the South

$$\tau_s = 1.3$$

From Fig. 2, it appears that when public spending in transport infrastructure improves in the South, transaction costs on the imported goods from the North decrease ($\tau_s = 1.3$), leading to a decrease in the price index and an increase in the effective demand in the South (Krugman 1991; Martin and Rogers 1995). Therefore, this can make the core-periphery equilibrium unstable and the South more attractive for manufacturing activities. In addition to the lower transaction costs on knowledge in the North ($\tau_N^{ICT} = 1.1$) also reinforced by the inputs-outputs linkages between industrial and ITES firms, this implies a relocation of industrial firms in the South since they will import intermediate ITES with lower telecommunication costs from the North. This result confirms the finding of Martin (1999) who showed that the decrease in the cost of innovation in the favored region may lead to more spatial distribution of incomes and productive activities.

However, when the public policy in the North is focused on the improvement of both infrastructures, there is no motivation for any manufacturing firm to relocate its activity in the South. As a result, the agglomeration occurs in the North. Given the inputs-outputs relationships between industrial and ITES firms, being concentrated in the North should be more profitable for firms than relocating in the South (Krugman 1991; Martin and Rogers 1995; Chatti et al. 2019). Therefore, firms continue to export their products to the South at lower transport costs. This result confirms the findings of Martin (1999) in which he showed that the improvement of interregional transportation infrastructures will increase the attractiveness of the North. As interregional trade becomes easier, it is less efficient to relocate industrial production in the South and firms can profit from the scale economies in the North. It is worth mentioning that this configuration must increase the spatial inequalities in industrial geography between countries.

Here, let us see the case of an ITES firm wanting to relocate its activity from the North to the South. By adopting the same methodology, we find the expression of profitability.

$$\frac{q_S^T}{q_N^T} = \tau_N^{-\mu\xi} \left(\frac{D_S^I}{D_N^I + (\tau_S^{ICT})^{1-\xi} (\tau_N^{ICT})^{\xi-1} D_S^I} (\tau_N^{ICT})^{\xi-1} + \frac{D_N^I}{D_N^I + (\tau_S^{ICT})^{1-\xi} (\tau_N^{ICT})^{\xi-1} D_S^I} (\tau_N^{ICT})^{1-\xi} \right) \quad (34)$$

Table 2 shows the parameters values of the concentration equilibrium. Fig. 3 shows that the technological agglomeration in the North is stable when the telecommunication cost is very low. Fig. 4 shows the same case with the presence of a lower telecommunication cost in the South but only with a level cost inferior to 1.3. Otherwise, the agglomeration equilibrium becomes instable when the telecommunication becomes sufficiently high.

Table 2: Parameters values

Parameters	α	μ	g_N	g_S	ξ	τ_N	$g_{\tau_N^{ICT}}$	τ_S^{ICT}
Fig. 3	0.6	0.6	0.3	0.2	5	1.2	0.3	3
Fig. 4	0.6	0.6	0.3	0.2	5	1.2	0.3	1.2

Fig. 3: Technological stability with higher telecommunication costs in the South

$$\tau_S^{ICT} = 3$$

Fig. 4: Technological stability with lower telecommunication costs in the South

$$\tau_S^{ICT} = 1.2$$

From the simulation results, it appears that relocating ITES firms in the South is possible in the reality when the transaction costs on knowledge flows become sufficiently high in the North. The speed of relocation will increase especially when the South invest more in the quality of telecommunication infrastructure. From the Fig. 4, it appears clearly that the concentration equilibrium is instable when the telecommunication cost exceeds 1.3 in the North and is equal to 1.2 in the South. In this case, it is more profitable for ITES firms to relocate in the South and to continue to export their intermediate services (ITES) to the North at lower transaction costs.

If the public policy in the North continues to improve telecommunication networks that consist to decrease transactions costs on knowledge, then it is less necessary for any ITES firm to relocate its production in the South. In this case, firms can fully profit by using an efficient access to telecommunication which enables them to producing and selling their intermediate services to manufacturing firms at lower costs. This can lead to a decrease in the price index and an increase in the real income of individuals. It is important also to note that this public policy induces more inequalities between both countries.

3.2.2. Dispersion Equilibrium

We suppose that ITES are equally distributed between both countries but manufacturing firms are supposed to be completely concentrated in the North. In these conditions, we get the following expressions.

$$\begin{aligned}\lambda_N^I &= \frac{\mu(1-\alpha)(1+g_{\tau^{ICT}})(2-g_N-g_S)}{2(2-\alpha\mu)}, \lambda_S^I = 0, w_N^I = w_S^I = 1 \\ w^T &= \frac{\alpha\mu(1+g_{\tau^{ICT}})(2-g_N-g_S)}{4\lambda^T(2-\alpha\mu)}\end{aligned}\quad (35)$$

The final expression of profitability for a single manufacturing firm looking to relocate its activity in the South is presented as follows.

$$\frac{q_S^I}{q_N^I} = \left(\frac{(1-g_S)}{1-g_N+(1-g_S)\tau_S^{1-\sigma}\tau_N^{\sigma-1}} \tau_N^{\sigma-1} + \frac{(1-g_N)}{1-g_N+(1-g_S)\tau_S^{1-\sigma}\tau_N^{\sigma-1}} \tau_N^{1-\sigma} \right) \quad (36)$$

Table 3 shows the parameters values of the concentration equilibrium. Fig. 5 shows that the industrial concentration in the North is always instable whatever the value attributed to the transportation cost. In other words, the profitability for one industrial firm desiring to relocate in the South exceeds the unity. In Fig. 6, despite the presence of lower transaction costs on goods produced in the South, the industrial agglomeration is still unstable in the North.

Table 3: Parameters values

Parameters	σ	τ_S	g_N	g_S
Fig. 5	5	2	0.2	0.1
Fig. 6	5	1.1	0.2	0.1

Fig. 5: Manufacturing stability with higher transport costs in the South
($\tau_s = 2$)

Fig. 6: Manufacturing stability with lower transport costs in the South
($\tau_s = 1.1$)

Based on the simulations results, it appears that the perfect repartition of ITES firms between both countries can make the industrial agglomeration in the North unstable. Fig. 5 and Fig. 6 show that the South is able to attract industrial firms despite its higher level of transportation costs ($\tau_s = 2$). This result corroborates the findings of Baldwin, Martin and Ottaviano (2001). These authors showed that the interregional knowledge diffusion has important impacts on the geography of industry. Nevertheless, the authors do not distinguish between infrastructures that may facilitate the diffusion of knowledge and do not take into account the role of public policies.

There are two main factors that can explain the relocation of industrial firms in the South. Firstly, when public spending is focused on the transportation infrastructure, this leads to lower prices of manufacturing goods imported from the North. This implies an increase in the real wage rate of workers and therefore in the demand for industrial goods in the South (Martin and Rogers 1995; Chatti et al. 2019). Secondly, workers in the North will support higher taxes on their wages in order to finance the provision of transportation infrastructures, thereby decreasing the demand for manufacturing goods. It appears in this case that the total impact is more relocation of industrial firms in the South, leading to less inequalities in terms of industrial geography between countries.

For attracting more industrial firms, the South must adopt two different policies. Firstly, it can apply a lower tax rate than that is applied by the North, in order to encourage the relocation of foreign firms. Similarly, the South can conserve its industrial agglomeration without imposing any public taxation. This result confirms the results of Martin and Rogers (1995). The authors showed that the public intervention is not desirable in the process of agglomeration especially for the North. In the same context, they suggested that if the improvement of domestic transport infrastructure could be financed by a third party (e.g. private sector or another region), then the negative effect on regional incomes would be null. Secondly, the South should develop its technological sector by investing more in human capital and telecommunications than in transport

infrastructures to profit from the knowledge flows; thus, attracting more industrial firms. This result confirms the finding of Martin (1999) and Riou (2003). The authors showed that the positive effect of the convergence of telecommunication infrastructure is consistent with the fact that a decrease in knowledge costs is better than a decrease in trading goods.

4. Public Telecommunication Policy and Welfare

The main objective is to examine the impacts of telecommunication policy on household welfare for the country which receives the public funds. We suppose that ITES firms are perfectly distributed between countries while manufacturing firms are fully concentrated in the North. Like Martin and Rogers (1995), Helpman (1995) and Chatti et al. (2019), the welfare level is derived from the indirect utility expression.

$$\Omega^T = w^T \left[\frac{\sigma^{-\sigma} (\sigma - 1)^{\sigma-1} (c^I)^{1-\sigma}}{(1-\alpha) F^I} \left(\lambda_N^I (P^T)^{-\alpha\sigma} \right) \right]^{\frac{-\mu}{1-\sigma}} \quad (37)$$

When replacing the equations of w^T , λ_N^I and P^T in (37), we get the final expression of the welfare level (*see Appendix A*):

$$\Omega^T = \left(\frac{\alpha}{4\lambda^T} \right)^{\frac{\alpha\sigma\mu}{1-\sigma}+1} \left(\frac{\mu(1+g_{\tau^{ICT}})(2-g_N-g_S)}{(2-\alpha\mu)} \right)^{\frac{\mu(\alpha\sigma-1)}{1-\sigma}+1} \left\{ \frac{\sigma^{-\sigma} (\sigma - 1)^{\sigma-1} (c^I)^{1-\sigma}}{2(1-\alpha) F^I} (\lambda^T)^{\frac{-\alpha\sigma}{1-\xi}} \left(1 + (\tau^{ICT})^{-\alpha\sigma} \right) \right\}^{\frac{-\mu}{1-\sigma}}$$

$$\frac{\partial \Omega^T}{\partial g_{\tau^{ICT}}} > 0$$

When public policy improves telecommunications that consists to decrease the transaction costs of knowledge flows, the household welfare for skilled workers will increase significantly. There are two principal factors that can explain the result. Firstly, when government spending improves the quality of telecommunication, skilled workers should pay a higher tax rate to finance the provision of this infrastructure, leading to a decrease in their real incomes. Secondly, the reduction of transactions costs in trading ITES between countries should decrease the price index and therefore increase the real incomes for households. The net effect is positive on the welfare of skilled workers. Contrary to Riou (2003), the welfare will be improved in both countries for skilled workers. This author showed that the welfare may decrease with an increasing quality level of telecommunication infrastructure.

From another side, we suppose that all productive activities are fully agglomerated in the North. In this case, the welfare level for qualified workers can be deduced using this following expression (*see Appendix B*):

$$\Omega_N^T = \left(\frac{\alpha}{\lambda_N^T} \right)^{\frac{-\alpha\sigma\mu}{1-\sigma}+1} \left\{ \frac{\mu \left((1-g_N) \left(1 + g_{\tau_N^{ICT}} \right) + (1-g_S) \right)}{1-\alpha\mu(1-g_N)} \right\}^{\frac{-\mu(\alpha\sigma+1)}{1-\sigma}+1} \left\{ \frac{\sigma^{-\sigma} (\sigma-1)^{\sigma-1} (c^I)^{1-\sigma}}{F^I} (\lambda_N^T)^{\frac{-\alpha\sigma}{1-\sigma}} \right\}^{\frac{-\mu}{1-\sigma}}$$

$$\frac{\partial \Omega_N^T}{\partial g_{\tau_N^{ICT}}} > 0$$

When public policy improves the telecommunication infrastructure in the North, leading to a decrease in the transaction costs in knowledge, the welfare level for skilled workers will be increased. The agglomeration of manufacturing firms in the North should increase the demand of intermediate ITES as a result of the reduction of transaction costs in knowledge flows and the inputs-outputs linkages. This should reduce the price index in the North and thus increase the real incomes for skilled workers. Contrary to Riou (2003), it seems that the net effect is positive on welfare since the first effect dominates the negative one due to public taxation on incomes.

Conclusions

This paper used a NEG model as an extension of Krugman and Venables (1995) and Martin and Rogers (1995) to investigate whether public expenditure influences industrial geography and household welfare. In this model, we made a clear distinction between two kinds of infrastructures; transport and telecommunication. In addition, we considered two main channels of diffusion of ideas and innovation: the mobile skilled workers and the efficient access to telecommunication. In the agglomeration state, we found that the relocation of industrial activities in the South is possible when the North invests more in telecommunication than in transportation infrastructures. This result confirms the findings of Martin (1999) who showed that the decrease in the costs of localized knowledge spillovers in the North can lead to more spatial distribution of incomes and productive activities. In the same vein, the South can profit from the relocation of intermediate ITES firms when the transactions costs of trading knowledge in the North are sufficiently high. Indeed, the speed of relocation depends to its ability to improve the quality of telecommunication.

In the dispersion state, we showed that the perfect repartition of ITES between countries can make the industrial agglomeration in the North unstable in the long term. This result confirms the findings of Baldwin, Martin and Ottaviano (2001). In terms of public policies, the South can adopt two options in order to attract more productive activities: (i) it can apply a lower tax rate on income comparing to the North, and (ii) it should invest more in human capital and telecommunication than in transport networks to attract foreign direct investments. The result corroborates the findings of Martin (1999) and Riou (2003) in which they showed the fact that a decrease in knowledge costs is better than a decrease in transport costs. In terms of household welfare, we found that when the public policy is focused on the improvement of telecommunication infrastructure, the welfare for skilled workers will be improved in both countries. Despite

the negative effect due to the public taxation, the net effect of this policy is positive on household welfare contrary to Riou (2003). This author showed that the welfare should decrease when the quality of telecommunication infrastructure improves.

Appendices

Appendix A

From the symmetric equilibrium configuration, we find these following equations,

$$\lambda_N^I = \frac{\mu(1-\alpha)(1+g_{\tau^{ICT}})(2-g_N-g_S)}{2(2-\alpha\mu)}, \lambda_S^I = 0, w_N^I = w_S^I = 1 \quad (\text{A.1})$$

$$w^T = \frac{\alpha\mu(1+g_{\tau^{ICT}})(2-g_N-g_S)}{4\lambda^T(2-\alpha\mu)}$$

$$(P_N^I)^{-\mu} = \left[\frac{\sigma^{-\sigma}(\sigma-1)^{\sigma-1}(c^I)^{1-\sigma}}{(1-\alpha)F^I} (\lambda_N^I (P^T)^{-\alpha\sigma}) \right]^{\frac{-\mu}{1-\sigma}} \quad (\text{A.2})$$

$$(P^T)^{-\alpha\sigma} = \left[\lambda^T (w^T)^{1-\xi} \left(1 + (\tau^{ICT})^{1-\xi} \right) \right]^{\frac{-\alpha\sigma}{1-\xi}} \quad (\text{A.3})$$

The indirect utility for a qualified worker is given by:

$$\Omega^T = w^T (P^I)^{-\mu} \quad (\text{A.4})$$

By replacing w^T in Eq. (A.4), we find the final expression as showed below.

$$\Omega^T = \left(\frac{\alpha}{4\lambda^T} \right)^{\frac{\alpha\mu}{1-\sigma}+1} \left(\frac{\mu(1+g_{\tau^{ICT}})(2-g_N-g_S)}{(2-\alpha\mu)} \right)^{\frac{\mu(\alpha\sigma-1)}{1-\sigma}+1} \quad (\text{A.5})$$

$$\left\{ \frac{\sigma^{-\sigma}(\sigma-1)^{\sigma-1}(c^I)^{1-\sigma}}{2(1-\alpha)F^I} (\lambda^T)^{\frac{-\alpha\sigma}{1-\xi}} \left(1 + (\tau^{ICT})^{1-\xi} \right)^{\frac{-\alpha\sigma}{1-\xi}} \right\}^{\frac{-\mu}{1-\sigma}}$$

Appendix B

From the asymmetric equilibrium configuration, we have these equations:

$$\lambda_S^I = 0, \lambda_N^I = \frac{\mu(1-\alpha)((1-g_N)(1+g_{\tau_N^{ICT}}) + (1-g_S))}{1-\alpha\mu(1-g_N)}, \lambda_S^T = 0, \lambda_N^T = \lambda_q^T, w_N^I = w_S^I = 1, \quad (\text{B.1})$$

$$w_N^T = \frac{\alpha\mu((1-g_N)(1+g_{\tau_N^{ICT}}) + (1-g_S))}{\lambda_N^T(1-\alpha\mu(1-g_N))}, w_S^T = 0$$

$$(P_N^I)^{-\mu} = \left[\frac{\sigma^{-\sigma}(\sigma-1)^{\sigma-1}(c^I)^{1-\sigma}}{(1-\alpha)F^I} (\lambda_N^I (P_N^T)^{-\alpha\sigma}) \right]^{\frac{-\mu}{1-\sigma}} \quad (\text{B.2})$$

$$\left(P_N^T\right)^{-\alpha\sigma} = \left[\lambda_N^T \left(w_N^T\right)^{1-\xi}\right]^{-\frac{\alpha\sigma}{1-\xi}} \quad (\text{B.3})$$

The indirect utility for a qualified worker is given by:

$$\Omega_N^T = w_N^T \left(P_N^I\right)^{-\mu} \quad (\text{B.4})$$

By replacing w_N^T in Eq. (B.4), we find the final expression as showed below.

$$\Omega_N^T = \left(\frac{\alpha}{\lambda_N^T}\right)^{\frac{-\alpha\sigma\mu}{1-\sigma}+1} \left\{ \frac{\mu \left((1-g_N) \left(1 + g_{\text{ICT}} \right) + (1-g_S) \right)}{1-\alpha\mu(1-g_N)} \right\}^{\frac{-\mu(\alpha\sigma+1)}{1-\sigma}+1} \left(\frac{\sigma^{-\sigma} (\sigma-1)^{\sigma-1} (c^I)^{1-\sigma}}{F^I} \right)^{\frac{-\mu}{1-\sigma}} \left(\lambda_N^T \right)^{\frac{\alpha\sigma\mu}{(1-\xi)(1-\sigma)}} \quad (\text{B.5})$$

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