# Uncertainty and coordination cost in vertically-linked industries: a model of New Economic Geography

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**Abstract**

(Grossman and Helpman 2004) have emphasized that the incompleteness of contracts in distant input-output linkages fosters agglomeration of downstream and upstream firms in the core region despite wage differential favoring to the periphery. Following this argument, this paper introduces uncertainty in input-output linkages in a NEG framework. We argue that uncertainty involves a coordination cost, which depends on: i) distance that prevents downstream firms to monitor fully their suppliers, ii) and the complexity of the production process. In a Venables (1996) framework, we show that coordination cost adds a new tradeoff for downstream firms that can halt the redispersion process. This result is in line with a new empirical phenomenon in Europe: the backsourcing, highlighted in (Dachs, Ebersberger, Kinkel, and Waser 2006).

**Key words:** firms location decision, uncertainty, coordination, input-output linkages, transfer cost.

# 1 Introduction

Many strands of literature have paid attention to the importance of trade costs in shaping firms location decisions. For instance, an important issue in the New Economic Geography literature (NEG) is to assess the nature of the relationship between the level of integration and the degree of agglomeration: once the agglomeration of industrial activities has occurred, do industries tend to redisperse or not with the pursuit of the integration process? At a first glance, theoretical predictions contrast according to the framework used, but mechanisms at work remain the same in standard NEG models namely (Krugman 1991) on the one hand, and (Krugman and Venables 1995), (Venables 1996) on the other hand (Puga and Ottaviano 1998). Indeed, the concentration of Increasing Return-to-Scale (IRS) industrial activities, which arises from mobile production factor, namely industrial workers in (Krugman 1991) and firms, notably due to input-output linkages, in (Krugman and Venables 1995), (Venables 1996), increases wages in the core region. In (Krugman 1991) the nominal wage differential is vanished by the intersectoral immobility, when agglomeration of all industrial labor force is completed, but real wage differential remains due to the home market effect, while in (Krugman and Venables 1995) and (Venables 1996) nominal wage differential persists. Then, a continuous fall in transport cost does not alter the core-periphery equilibrium in the former model. However in the latter, since intermediate goods become cheaper to trade, wage differential, local competition effect and demand linkages with final consumers, lead to a redispersion process of industrial activities, breaking the core-periphery equilibrium. In short, the nature of the relationship between the level of integration and the degree of agglomeration, whether monotonic or "Reverted U-shaped", depends on two assumptions: the nature of labor mobility and the presence of input-output linkages (Puga 1999). However some papers emphasized whether the fall in transport cost benefit to upstream or downstream sector is also crucial (Amiti 2004), (Alonso-Villar 2005) in determining the nature of this relationship.

On the other hand, the so-called "New" New Trade Theory (NNTT) and especially (Grossman and Helpman 2004) have highlighted that, despite wage differential between the core and the periphery, firms migration can be prevented by the incompleteness of contracts. They pointed out that distance between downstream and upstream firms prevents firms to fully monitor their supplier because of the incompleteness of contracts. Then, the incompleteness of contracts appears also important in firms decision locations.

From this literature, we consider that contract incompleteness introduces uncertainty in input-output linkages. We argue that the inability for downstream firms to fully monitor their suppliers induces a coordination cost. This uncertainty has two determinants: geographical distance between upstream and downstream firms, and the complexity of production process, captured by the number of varieties. In this paper, we have tried to combine both literatures in order to show that a fall in transport does not always result in a redispersion of economic activities. In order to study how the presence of coordination costs in distant input-output linkages changes the pattern of firms location, we address this issue within a two-regions model *à la* Venables (1996), introducing a coordination cost associated to the distant purchase of intermediate goods.

Our main result is that the presence of this coordination cost can prevent redispersion from occurring for very low transport costs, despite wage differential between regions. More precisely, we are able to assess condition on coordination cost under which the relationship between the level of transport cost and the degree of agglomeration switch from a monotonic nature to a "Reverted U-Shaped" one. Above a critical value of coordination cost parameter, agglomeration stands and below it industrial activities are evenly split across regions.

The rest of the paper is organized as follows. The next section describes the consequence of uncertainty in vertical linkages, involving coordination cost in addition to transport costs in the trade of intermediate goods. The section 3 presents the model which extends the original framework of Venables (1996) with the coordination cost expressed in section 2. The section 4 investigates, both analytically and numerically, conditions under which a core-periphery outcome is sustainable in this setting. Finally, some concluding remarks are presented in section 5.

## 2 Uncertainty in input-output linkages

In this section, we describe the linkages between upstream and downstream sectors characterized by uncertainty. Final goods are produced with labor and differentiated intermediate goods whereas the production of intermediate goods requires labor only.

When a downstream firm purchases an intermediate good to an upstream firm, it is expecting that the good will have some required characteristics, in a infinite intermediate goods space of specifications (Grossman and Helpman 2002), that have been usually specified in the contract linking both firms. However, the very nature of such contracts is incomplete in the sense that downstream firms are never able to monitor fully their suppliers (Grossman and Helpman 2004), and especially with respect to goods characteristics. Let $z$ represents the distance (see figure 1), in a specific metric, between the expected (optimal) characteristics and the real ones. This $z$ value is a random variable. Its density function is denoted $g(z)$, defined in $R^+$.

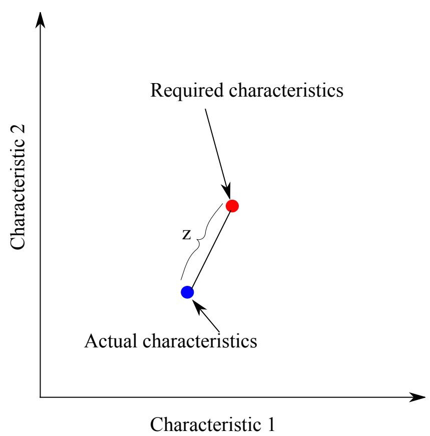


Figure 1: Signification of $z$ in a two-characteristics space

The gap, between the expected set of characteristics and what the firm actually get, creates an additional cost in the production process. Indeed, the firm will need to adjust intermediate goods characteristics, the level of adjustment depending on $z$ value.

We consider that $g(z)$ follows an exponential law with parameter $\gamma$:

$$g(z) = \gamma e^{-\gamma z}$$

The expected value of $z$ is given by:

$$E(z) = \frac{1}{\gamma}$$

From this equation, we notice that the higher is $\gamma$, the higher is the probability that the set of characteristics is close to the expected one. We assume that both geographical distance and complexity of production process, captured by the number of varieties ($n_I$), influence the value of $\gamma$. Hence, $\gamma$ is more likely to be low with a large number of differentiated intermediate goods used in the production process and with geographical distance, which imply a higher need of coordination between upstream and downstream firms. Indeed, downstream firm needs to organize the assembly of a larger set of differentiated inputs and the more distant it is from its suppliers, the smaller is the probability that the set of characteristics is close to those expected. In short, distance introduces uncertainty about what we'll finally get. We formalize this idea in assuming that $\gamma$ is an inverse function of complexity $n_I$ and geographical distance $d$:

$$\gamma = \frac{1}{\phi d n_I} \tag{1}$$

$\phi > 0$ is a key parameter since it gives the sensitivity of the variable $\gamma$ to both determinants ($d$ and $n_I$). For a given distance and a given level of complexity, the larger is $\phi$, the bigger will be the negative impact on the probability that characteristics match with the expected ones. Moreover, from eq.(1), we notice that the higher is the geographical distance between trade partners, and the higher is the number of varieties entering in the production process, the lower is the probability that characteristics will be close to the expected one.

Then, the consequences of a low value of $\gamma$ (high value of $z$) can all be evaluated in term of cost: the so-called *coordination cost.* This cost has two main sources: complexity of production process and geographical distance between upstream and downstream firms. For the sake of simplicity, we assume that the level of coordination costs is proportional to the $z$. Let $c_O$ denotes the coordination cost. Using the Samuelson formulation of iceberg-type costs, this cost will be introduce in the model (section 3) as multiplicative to the intermediate good price[1]:

$$c_O = p_i \times z$$

where $p_i$ is the intermediate good price of a $i$ variety, for $i \in [1, n_I]$. As $c_O$ is function of $z$, it as a random variable. The expected cost is then given by:

$$E(c_O) = p_i \times E(z)$$

$$E(c_O) = \frac{p_i}{\gamma}$$

Reintroducing eq.(1) into this equation yields to:

$$E(c_O) = p_i \times \phi d n_I$$

Finally, Let $t_I$ denotes the interregional transfer cost of intermediate good. $t_I$ encompasses both the transport cost, denoted $\tau$ and the coordination cost, and can be written[2]:

$$t_I = (\tau + \phi d n_I) \tag{2}$$

Our specification of transfer costs for intermediate inputs has two implications that deserve some comments. First, it implies that only contractual relationships between *distant* suppliers and consumers involve the type of uncertainty that gives rise to coordination costs. This assumption is made for the sake of simplicity. In reality, contracts between local upstream and

[1]An appropriate specification would contain a proportionality coefficient, such as $c_O = \psi \times p_i \times z$. However, we can choose $\phi$ so as $\psi$ is normalized to unity.

[2]We assume the downstream producers are risk-neutral.

downstream firms are also incomplete. However, our main point is that contracts between distant partners are far more risky that contract between local ones. The second interesting feature of our specification is that coordination costs increase with the *total* number of intermediate goods use in production, which in a NEG framework, involves an endogenous evolution of this cost.

# 3 Coordination cost in a Venables (1996) framework

The basic structure of the Venables model is a two-regions setting. Regions 1 and 2 are endowed with the same amount of labor which mobile across sectors within each region, but immobile across regions. Three different sectors are potentially active in each region. First, a traditional sector, characterized by perfect competition, produces an homogeneous good under decreasing returns-to-scale. Second, two industrial sectors, characterized by imperfect competition *à la* Chamberlin, produce horizontally differentiated goods under increasing returns-to-scale. Among these two sectors there is the upstream industry offering intermediate goods to the downstream industry. These two sector composed a full input-output structure. Traditional goods are tradeable without cost whereas trade in industrial goods involves transport costs. Let $\tau_{12}$ represents the exogenous transport cost parameter[3] from region 1 to region 2 which is the same for both intermediate and final good. Moreover, trade of intermediate goods involves a coordination cost $\phi n_I d$ presented in the previous section. As we assumed in the previous section, only interregional flows of intermediate goods bear coordination cost, such as $d = 1$ for distant purchase and $d = 0$ for local one. In order to keep a concordance between notations of final goods transfer cost and intermediate goods ones, inter-regional transfer cost for final goods is denoted $t_F$, and simply equals to $\tau$, and inter-regional transfer cost for intermediate goods is denoted $t_I$ and equals to $(\tau + \phi n_I)$.

The introduction of coordination costs modifies the equilibrium and thus

[3] We assume $\tau_{12} = \tau_{21}$, so from here we will drop subscripts.

change firms localization patterns. Indeed, taking into account uncertainty in distant vertical linkages, adds a trade-off in the decision of localization for downstream firms. In this section, we first describe how the presence of coordinations costs changes the profit equation in the downstream sector. Then we show how these changes impact firms decisions in the two others sectors, respectively the upstream industrial sector and the agricultural one. Finally, we present the consumer behavior.

### 3.1 Downstream sector

The downstream sector in region $k$, for $k \in \{1,2\}$, is composed of $n_{Fk}$ firms, each of them producing a different variety $j$ of final goods, for $j \in [1, n_{Fk}]$. The production of any variety $j$ requires the combination of labor and an intermediate goods composite, represented by a Constant-Elasticity-of-Substitution (CES) function[4]. The production function of a representative downstream firm takes the following form:

$$AL_{Fk}^{1-\mu} X_{Ik}^{\mu} = f + x_{jk}, \forall k \in \{1,2\} \tag{3}$$

where $L_{Fk}$ and $X_{Ik}$ are respectively the quantity of labor and of intermediate goods composite required to produce a quantity $x_{jk}$ of the variety $j$ in region $k$. $\mu$ and $(1-\mu)$ account respectively for the share of intermediate input and labor used in production. These factor quantities are the ones necessary to cover both the fixed cost of production, $f$ and the variable cost depending on the quantities produced $x_{jk}$. $A$ is a scale parameter that we normalize to $A = \mu^{-\mu}(1-\mu)^{\mu-1}$ in order to reach more tractable forms of demand functions. Finally, the intermediate input $X_{Ik}$, defined as a CES composite of intermediate goods, can be written as:

$$X_{Ik} = \left( \sum_{i=1}^{n_{Ik}} x_{ikk}^{\frac{\sigma-1}{\sigma}} + \sum_{i=1}^{n_{Ik'}} x_{ik'k}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \forall k \in \{1,2\} \tag{4}$$

Notice that $x_{ikk}$ represents varieties produced and supplied region $k$ while

[4]This technology ensures that downstream firms use as much different varieties of intermediate goods as available.

$x_{ik'k}$ represents varieties produced $k'$ and sent to $k$. $\sigma$ denotes the elasticity of substitution between two different varieties $i$ . The factor demand functions, derived from the cost minimization program of a downstream firm, which after the normalization of $A$, equal to:

$$X^*_{Ik} = \mu w_k^{1-\mu} P_{Ik}^{\mu-1} (f + x_{jk}) \tag{5}$$

and

$$L^*_{Fk} = (1-\mu)\, w_k^{-\mu} P_{Ik}^{\mu} (f + x_{jk}), \forall\, k \in \{1,2\} \tag{6}$$

where $w_k$ is the wage rate prevailing in region $k$. $P_{Ik}$ is the price index of the intermediate input in region $k$. It is composed of the prices of intermediate goods sold in region $k$ , produced either in the local region or in the distant one.

$$P_{Ik} = \left[ \sum_{i=1}^{n_{Ik}} (p_{ik})^{1-\sigma} + \sum_{i=1}^{n_{Ik'}} (p_{ik'} t_I)^{1-\sigma} \right]^{\frac{1}{1-\sigma}}, \forall\, k \in \{1,2\} \tag{7}$$

where $p_{ik}$ and $p_{ik'}$ are the individual free-on-board (f.o.b) intermediate goods prices of a $i$ variety produced respectively in $k$ and $k'$. From section 2, we defined $t_I$ as the transfer cost of intermediate goods which encompasses both transport costs and coordination costs.

Thus, the optimal cost function of a typical downstream firms is given by:

$$C^*_{jk} = w_k^{1-\mu} P_{Ik}^{\mu} (f + x_{jk}), \forall\, k \in \{1,2\}$$

Then, we denote $c_{jk}$ the marginal cost a downstream firm in region $k$, producing a variety $j$ of final good. It equals to:

$$c_{jk} = w_k^{1-\mu} P_{Ik}^{\mu}, \forall\, k \in \{1,2\}$$

The global demand addressed to a variety $i$, for $i \in [1, n_{Ik}]$ of intermediate goods is derived from a maximization program of the aggregate $X_I$ with respect to the share of production cost spent on intermediate goods in region $k$, for $k \in \{1,2\}$. The total spending on intermediate goods in a given region is:

$$E_{Ik} = \mu n_{Fk} c_{jk} \left(f + x_{jk}\right), \forall\, k \in \{1, 2\}$$

The zero-profit condition holds in the general equilibrium, it follows that $E_{Ik}$ is also defined:

$$E_{Ik} = \mu n_{Fk} p_{jk} x_{jk}, \forall\, k \in \{1, 2\} \tag{8}$$

With $x_{jk} = x_{jkk} + x_{jkk'}$, where $x_{jkk}$ represents the amount of final good produced and supplied in the local market and $x_{jkk'}$ represents the amount of final good locally produced and shipped to the distant market.

The maximization-program of $X_I$ with respect to (eq.(8)) gives the following demand of intermediate good for any variety $i$, produced in $k$, from a downstream firm located in $k'$:

$$x^d_{ikk'} = E_{Ik'} P^{\sigma-1}_{Ik'} \left(p_{ik} t_I\right)^{-\sigma} \tag{9}$$

Demand quantities of intermediate goods are lowered by the presence of coordination cost. This reinforces the incentives of upstream firms to locate close to their suppliers. Moreover, as we can notice in eq.(9), this coordination cost is not lowered by the fall in transport cost ($\tau$), downstream firms have more incentives to be close to their suppliers in order to save coordination cost. Indeed, when transport costs fall, the number of firms increases, which makes the coordination cost grow.

The profit of each downstream firm in region $k$ is equal to:

$$\pi_{jk} = p_{jk} x_{jk} - w^{1-\mu}_k P^{\mu}_{Ik} \left(f + x_{jk}\right), \forall\, k \in \{1, 2\}$$

Thus the price of any variety of final goods in region $k$ is given by:

$$p_{jk} = \frac{\sigma}{\sigma - 1} c_{jk}, \forall\, k \in \{1, 2\} \tag{10}$$

From the zero-profit condition, the supply of a variety $j$, for $j \in [1, n_{Fk}]$, of final good produced in $k$ for the local market ($k$) and for the distant one ($k'$) is:

$$x_{jk} = x_{jkk} + x_{jkk'} = f\left(\sigma - 1\right) \tag{11}$$

## 3.2 Upstream sector

The upstream sector in region $k$, for $k \in \{1,2\}$, is composed of $n_{Ik}$ firms producing different varieties $i$, for $i \in [1, n_{Ik}]$, of intermediate goods. The production technology of intermediate goods requires only labor and takes the following form for a firm in region $k$:

$$L_{Ik} = f + x_{ik}, \forall k \in \{1,2\} \tag{12}$$

where $L_{Ik}$ is the quantity of labor required to cover both the fixed cost $f$ and the variable cost $x_{ik}$. The cost of an upstream firm in region $k$ is simply:

$$C_{ik} = w_k L_{Ik}, \forall k \in \{1,2\}$$

The marginal cost of a upstream firm in region $k$, producing a variety $i$ of intermediate good is then:

$$c_{ik} = w_k, \forall k \in \{1,2\}$$

Firms profit equals to:

$$\pi_{ik} = p_{ik} x_{ik} - w_k \left(f + x_{ik}\right), \forall k \in \{1,2\} \tag{13}$$

Derivating profits with respect to quantities we obtain the equilibrium price:

$$p_{ik} = \left(\frac{\sigma}{\sigma - 1}\right) c_{ik}, \forall k \in \{1,2\} \tag{14}$$

Introducing eq.(14) into eq.(13), yields to the global supply of intermediate goods ($x_{ik}$) in region $k$:

$$x_{ik} = x_{ikk} + x_{ikk'} = f\left(\sigma - 1\right), \forall k \in \{1,2\} \tag{15}$$

Notice $x_{ikk}$ are the quantities of intermediate good produced and locally supplied and $x_{ikk'}$ are the quantities produced in $k$ and shipped to distant market $k'$.

### 3.3 Agricultural sector

The agricultural sector produces a freely tradeable homogeneous good $X_A$, under perfect competition. The production function is strictly concave and defined such as:

$$X_{Ak} = F(L_{Ak}) = aL_{Ak}^{\alpha}, \forall\, k \in \{1, 2\}$$

The only input used is labor $L_{Ak}$. $\alpha$ is interpreted as the elasticity of production with respect to labor. We assume that $\alpha \in ]0, 1[$, which implies decreasing returns as in (Venables 1996). The parameter $a$ is a productivity parameter. Then, profits are equal to:

$$\pi_{Ak} = F(L_{Ak}) - w_k L_{Ak}, \forall\, k \in \{1, 2\} \tag{16}$$

The profit-maximization program in agricultural sector gives the equilibrium amount of labor in agriculture:

$$L_{Ak}^{*} = \left(\frac{w_k}{\alpha a}\right)^{\frac{1}{\alpha-1}}, \forall\, k \in \{1, 2\} \tag{17}$$

Introducing eq.(17) in eq.(16), gives equilibrium profit:

$$\pi_{Ak}^{*} = a\left[\left(\frac{w_k}{\alpha a}\right)^{\frac{1}{\alpha-1}}\right]^{\alpha} - w_k\left(\frac{w_k}{\alpha a}\right)^{\frac{1}{\alpha-1}}, , \forall\, k \in \{1, 2\} \tag{18}$$

After some simplifications, we obtain the following equilibrium profit equation:

$$\pi_{Ak}^{*} = a^{\frac{1}{1-\alpha}}(1-\alpha)\left(\frac{1}{\alpha}\right)^{\frac{\alpha}{\alpha-1}} w_k^{\frac{\alpha}{\alpha-1}} > 0, \forall\, k \in \{1, 2\} \tag{19}$$

The strictly positive profit comes from the concave technology of production. Profits are then Ricardian rents.

### 3.4 Consumers

Consumers have identical preferences between regions. They are endowed with the same utility function:

$$U = X_A^{1-\beta} X_F^{\beta} \tag{20}$$

From this equation, we notice that consumption is split between agricultural goods $X_A$ and final goods $X_F$ , which account respectively of a share $(1-\beta)$ and $\beta$ of their income. Industrial goods consumption is characterized by a *preference of variety*[5]. Their income are drown, as a wage $w_k$ from agricultural and industrial sector, and also as a share of profits in agricultural sector[6] $\pi^*_{Ak}$. The total spending on final goods in region $k$ is denoted $E_{Fk}$ and defined by:

$$E_{Fk} = \beta \left( \pi^*_{Ak} + w_k L_k \right), \forall\, k \in \{1, 2\} \tag{21}$$

$X_{Fk}$ is, similarly than $X_{Ik}$ (eq.(4)), a composite of $j$ varieties of final good, for $j \in [1, n_F]$:

$$X_{Fk} = \left( \sum_{j=1}^{n_{Fk}} x_{jkk}^{\frac{\sigma-1}{\sigma}} + \sum_{j=1}^{n_{Fk'}} x_{jk'k}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \forall\, k \in \{1, 2\} \tag{22}$$

Where $x_{jkk}$ are quantities of final good produced in $k$ and supplied to local market $(k)$ and $x_{jk'k}$ are quantities produced in the distant market $k'$ and sent to $(k)$. Notice that $\sigma$, for $\sigma > 1$, is the elasticity of substitution between two different varieties. The final demand for a variety $j$ addressed by consumers to downstream firms in $k$ comes from local $(x^d_{jkk})$ and distant market $(x^d_{jkk'})$ such that the final demand is defined by:

$$x^d_{jk} = x^d_{jkk} + x^d_{jkk'}, \forall\, k \in \{1, 2\} \tag{23}$$

Consumers demand function derivating from the second step of consumer maximization program is:

[5]Similarly to the downstream sector, it ensures that consumers will buy as many varieties as available in the economy.

[6]Following (Venables 1996), we assume that agricultural profits are equally divided among farmers. Industrial sectors have no profits since the non-profit condition holds in the long-run equilibrium.

$$x^d_{jkk'} = E_{Fk} P^{\sigma-1}_{Fk} \left(p_{jk'} t_F\right)^{-\sigma}, \forall\, k \in \{1,2\} \tag{24}$$

Where $t_F$ is the transport cost parameter which has the multiplicative form of the so-called *iceberg transport costs*, which is simply equal to $\tau$.

The consumer demand for an individual variety $j$ depends on the share of income spent on industrial goods $E_{Fk}$, the price index in the region $k$ $P_{Fk}$, and negatively affected by the price of an individual variety $j$ from the distant market $k'$. The price index in region $k$ is:

$$P_{Fk} = \left[\sum_{j=1}^{n_{Fk}} \left(p_{jk}\right)^{1-\sigma} + \sum_{j=1}^{n_{Fk'}} \left(p_{jk'} t_F\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}, \forall\, k \in \{1,2\} \tag{25}$$

The total amount of final goods produced in region $k$ $x_{jk}$ is the sum of amount of varieties sold in region $k$ $x_{jkk}$ and the amount of varieties sent to the distant market $k'$ $x_{jkk'}$. It is derived from the non-profit condition (long-run equilibrium):

$$x_{jk} = x_{jkk} + x_{jkk'} = f\left(\sigma - 1\right), \forall\, k \in \{1,2\} \tag{26}$$

The clearance condition of labor market is represented by the total labor supply per region, defined as:

$$L_k = L^*_{Ak} + n^*_{Fk} L^*_{Fk} + n^*_{Ik} L^*_{Ik}, \forall\, k \in \{1,2\} \tag{27}$$

# 4 Results: coordination cost as a limit to re-dispersion

In this model, the presence of coordination cost strengthens upstream-downstream linkages. Then, downstream firms prefer the proximity of upstream firms in order to save transfer costs, and especially coordination cost, than the proximity to their demand in periphery, which would also lower wages. That's why we first assess the condition of $\phi$ under which the core-periphery equilibrium is stable. Since this cost is borne by downstream firms we specify the conditions under which the core-periphery equilibrium is stable. And second, we run simulations in order to complete the study of this model.

## 4.1 Analytical stability of the core-periphery equilibrium

The analysis of the stability of an equilibrium asks the question: what will happen if a deviant firm moves from one region to the other? Will it create incentives for more firms to get to this region? Or will the firm go back to the origin region? If firms have incentives to move, it changes the nature of equilibrium the equilibrium is unstable and if not the equilibrium is stable. We study the limit of the ratio of the demand addressed to the deviant firm in the periphery and the demand addressed to a firm in the core region[7] for low value of transport costs.

Let assume that the agglomeration of industrial activities takes place in region 1. The demand of final goods addressed to a firm in region 1 is $x_{j1}$. This demand comes from local consumers ($x_{j11}$) and from consumers in region 2 ($x_{j12}$). This core-periphery configuration is an equilibrium, which means that profits are equal to zero in region 1. As industrial production takes place only in region 1, the total industrial demand is satisfied by firms located in region 1. What will happen then if a firm leaves region 1 to region 2?

Price indexes in downstream sector in regions 1 and 2 can be express as:

$$P_{F1} = n_{F1}^{\frac{1}{1-\sigma}} p_{j1} \tag{28}$$

$$P_{F2} = n_{F1}^{\frac{1}{1-\sigma}} p_{j1} \tau \tag{29}$$

At the equilibrium, prices are equal for any variety so the price index depends on the number of varieties. Then, we look at final goods prices, which are equal to:

[7] The answer follows the methodology of (Puga 1999)

$$p_{j1} = \left(\frac{\sigma}{\sigma-1}\right) c_{j1} \; where \; c_{j1} = w_1^{1-\mu} P_{I1}^{\mu} \tag{30}$$

$$p_{j2} = \left(\frac{\sigma}{\sigma-1}\right) c_{j2} \; where \; c_{j2} = w_2^{1-\mu} P_{I2}^{\mu} \tag{31}$$

Thus index prices ratio are equal to:

$$\frac{p_{j2}}{p_{j1}} = \frac{w_2}{w_1} \tag{32}$$

$$\frac{p_{j2}}{p_{j1}} = \left(\frac{w_2}{w_1}\right)^{1-\mu} (\tau + \phi n_I)^{\mu} \tag{33}$$

Using equation (33) into demand equation (24) yields to:

$$x_{j1} = \frac{E_{F1} + E_{F2}\tau^{-1}}{n_{F1} p_{j1}} \tag{34}$$

$$x_{j2} = \left(\left(\frac{w_2}{w_1}\right)^{1-\mu} (\tau + \phi n_I)^{\mu}\right)^{-\sigma} \left(\frac{E_{F1}\tau^{-\sigma} + E_{F2}\tau^{\sigma-1}}{n_{F1} p_{j1}}\right) \tag{35}$$

The stability of this equilibrium is shown through the limit of $\frac{x_{j2}}{x_{j1}}$ for small value of transport costs. If $\lim_{\tau \to 1} \left(\frac{x_{j2}}{x_{j1}}\right) < 1$, equilibrium is stable. Conversely, if $\lim_{\tau \to 1} \left(\frac{x_{j2}}{x_{j1}}\right) > 1$, agglomerated equilibrium is unstable.

Then, the ratio of final goods demand is given by:

$$\frac{x_{j2}}{x_{j1}} = \left(\frac{w_2}{w_1}\right)^{-\sigma(1-\mu)} (\tau + \phi n_I)^{-\sigma\mu} \tau^{-\sigma} \left(1 + \frac{E_{F2}\left(\tau^{2\sigma-1} - 1\right)}{E_{F1} + E_{F2}\tau^{-1}}\right) \tag{36}$$

After some simplification the limit of final goods demand can be written as:

$$\lim_{\tau \to 1} \left(\frac{x_{j2}}{x_{j1}}\right) = \lim_{\tau \to 1} \left[\left(\frac{w_2}{w_1}\right)^{\sigma(1-\mu)} (1 + \phi n_I)^{-\sigma\mu}\right] \tag{37}$$

The limit depends on $\frac{w_1}{w_2}$, $\phi$, $n_I$. Wages ratio and the number of intermediate varieties $n_I$ are endogenously determined. However we can establish a simple relationship between $\frac{w_1}{w_2}$, $\phi$ and $n_I$ such as the core-periphery equilibrium is stable. This leads to the determination of a value of $\phi$ for which the core-periphery equilibrium is stable.

$$\lim_{\tau \to 1} \left[ \left( \frac{w_2}{w_1} \right)^{\sigma(1-\mu)} (1 + \phi n_I)^{-\sigma\mu} \right] < 1$$

$$\left( \frac{w_2}{w_1} \right)^{\sigma(1-\mu)} (1 + \phi n_I)^{-\sigma\mu} < 1$$

$$\phi > \frac{\left( \frac{w_2}{w_1} \right)^{\frac{1-\mu}{\mu}} - 1}{n_I} \tag{38}$$

The right hand side of this inequation is the critical value of $\phi$. As long as the value of $\phi$ respects this condition, agglomeration stands. Unlike in Venables (1996), a decrease in transport cost is not sufficient to involve redispersion despite wage differential favoring the periphery region. However, as the critical value of $\phi$ depends on endogenous variables such wages ($w_1$, $w_2$) and the number of upstream firms ($n_I$), running simulations appears to be necessary in order to try to quantify how much this critical value is.

## 4.2 Numerical results

The very strong non-linearity of this kind of models restricts analytical investigation. Although we have determined the non-redispersion condition (eq.(38), this relation still depends on endogenous variables. That's why we need to complete our study with simulations exercises. We run simulations keeping the same parameter values[8] than Venables in order to refer to it as a benchmark[9]. Nevertheless, compared to the latter model, we need to specify an additional parameter which correspond to the exogenous part of coordination cost: $\phi$. In order to derive relevant results from these simulations, we need to give to $\phi$ a realistic value. At a first glance, this intention seems a

[8]See Appendix for the detailed values.

[9]Notice that when $\phi = 0$ we identify the Venables framework.

quite tough task. Indeed, the coordination cost comes from uncertainty and it is not easy to quantify. However, if we relate our specification of transfer cost, proper to the interregional exchange of intermediate goods, to a broad definition of trade cost such as (Anderson and van Wincoop 2004)[10], we can found a realistic value around 6 % of trade cost.

Thus, we run simulation for two different value of $\phi$. The first simulation sequence is realized when $\phi = 0.01$. For this $\phi$ value, the endogenous part of coordination cost $\phi n_I$ accounts for 6 % or 7.33 %[11] of transfer cost $t_I$, wether $\tau = 1.1$ or $\tau = 1.01$. In the second one, we consider a lower level of coordination $\phi = 0.0001$. For this value, the endogenous part of coordination cost $\phi n_I$ represents 0.07 % or 0.09% of transfer cost, depending on the value of $\tau$. Notice that the fall in transport cost makes increase the endogenous part of coordination cost. So the coordination cost $\phi n_I$ represents a higher share of transfer cost when transport cost $\tau$ decreases. Each simulation exercice have been done for two different values of transport cost $\tau$ which are, in this literature, considered as low value namely: $\tau = 1.1$ and $\tau = 1.01$.

Figures 2 and 3 represent equilibrium spatial configurations related to a coordination cost value close to Anderson and van Wincoop estimations. The $x$ axis is the share of upstream firms in a region $k$, for $k \in \{1, 2\}$ while the $y$ axis is the share of downstream firm in a region $k$. The blue curve represents equilibrium on downstream sector ($\pi_{jk} = 0, \forall\, k \in \{1, 2\}$), and depends on the share of upstream sector in this region $n_{Ik}\, \forall\, k \in \{1, 2\}$, (such that $\pi_{i1} = 0$). Likewise, the green curve gives the same information about the upstream sector, namely the sector equilibrium ($\pi_{ik} = 0, \forall\, k \in \{1, 2\}$) which depends on the share of downstream sector in this region $n_{Fk}\, \forall\, k \in \{1, 2\}$, (such that $\pi_{j1} = 0$). Thus, the intersection of curves represents the general equilibrium,

[10] According to Anderson and van Wincoop, trade cost broadly defined encompasses direct measures as transport cost, tariff, and indirect measures as language sharing, border sharing, and most interesting for our concern information cost and contract enforcement. To the extent that the nature of the so-called coordination cost is a mix between a lack of information about input specification which arises with distance and from the incompleteness of contracts, we take these costs as a proxy of coordination cost.

[11] According to (Anderson and van Wincoop 2004) information cost represents 6 % so our estimations of coordination cost, defined as a sum of information cost and contract enforcement cost seem consistent with this study.

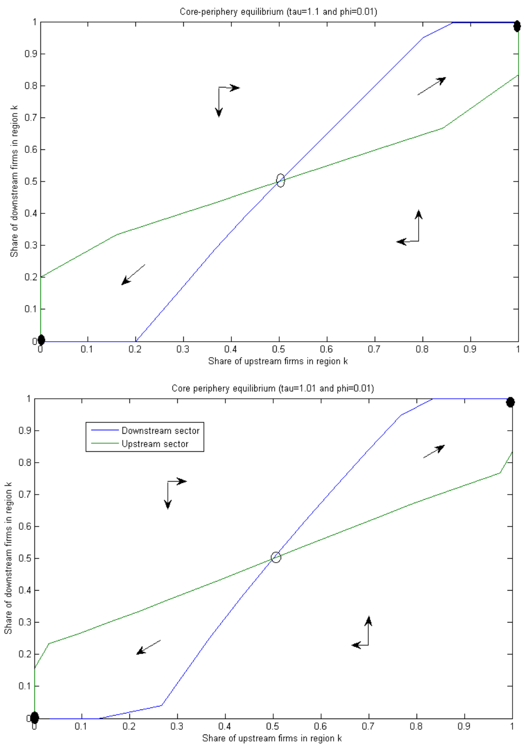


Figure 2: Impact of a fall in $\tau$ when $\phi = 0.01$

where ($\bullet$) denotes stable equilibrium and ($\circ$) unstable equilibrium.

For both level of transport cost: $\tau = 1.1$ and $\tau = 1.01$, only one kind of equilibrium is stable (see figure 2): core-periphery, which stands for both region $k \in \{1, 2\}$, while the symmetric equilibrium is unstable. It means that the symmetric equilibrium can exist but the migration of a firm would make switched to the core-periphery equilibrium. This result contrasts with Venables. In the latter, concentration of IRS activities arises for intermediate value of transport cost. As soon as the core-periphery equilibrium emerges the strength of vertical linkages, which determines the concentration of industrial activities, is given by the value of transport cost. From an intermediate value of transport cost, further fall in transport cost changes firms location decision. Indeed, when intermediate goods become cheaper to trade, firms prefer favoring of differential wage in periphery than saving transport cost. In this model, the strength of vertical linkages depends on both transport and coordination costs. Thus, a fall in transport cost is not sufficient to bring redispersion. In addition, the endogenous evolution of coordination cost implies that a fall in transport cost is not combined with a fall in coordination cost. As a result, this scenario shows that, for this specific value $\phi$, and even for a lower value of transport cost, the presence of coordination halts the redispersion process despite the presence of interregional wage differential.

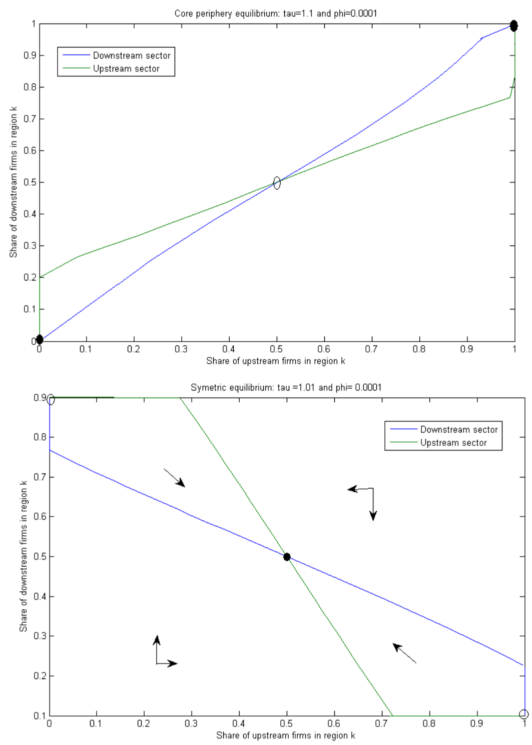


Figure 3: Impact of a fall in $\tau$ when $\phi = 0.0001$

Figure 3 plots spatial configuration for a low level of coordination, where the exogenous part $\phi$ is settle to 0.0001 and total coordination cost $(dn_I)$ represents only 0.19 % of transfer cost $(t_I)$. It sketches different spatial configurations. When transport cost are equal to 1.1, equilibrium spatial configuration are similar to previous figure: only core-periphery is stable. The explanation of this concentration of industrial remains the same than the previous figure. However, a fall in transport cost leads to a redispersion of industrial activities. For this value of $\phi$ and $\tau$, firms benefit from wage differential, less competition and final consummer linkages in the periphery. In this scenario, the persence of coordination does not halt redispersion of industrial activities but postpon it. Indeed, in Venables redispersion occurs a higher level of transport than 1.01.

Hence, these simulations exercises allow us to highlight two points: the presence of coordination can either halt or postpone redispersion of industrial activities, depending on the coordination cost value.

# 5 Concluding remarks

Within standard models of NEG, distance impacts the same way upstream-downstream linkages and final consumer-downstream firm linkages. However, introducing uncertainty in input-output linkages through a coordination cost, we show that distance strengthens input-output linkages. Thus, despite the presence of input-output linkages and the interregional mobility of workers, a fall in transport cost is not sufficient to lead to redispersion of industrial activities. This result is in line with a new phenomenon in Europe highlighted in the European Manufacturing Survey (Dachs, Ebersberger, Kinkel, and Waser 2006). Some European firms which have outsourced their activities in Europe have backsourced some years later because of an underestimation of global production cost. The cost mentioned by these firms were coordination costs and communication costs. This empirical study points out that, in France for instance, 46 % of investigated firms have outsourced a part of their production and one third of these firms have finally backsouced.

Moreover, the fact that a fall in transport does not always result in a re-dispersion of economic activities echoes several empirical literature. Firstly, despite the suitability of this theoretical framework for the European integration process, there are some empirical evidences supported that core-periphery structures are still persuasive in Europe (Combes and Overman 2004). There have been several attempts in the NEG literature to explain this so-called European Paradox. Among them, Puga (1999) and (Faini 1999) emphasize institutional labor markets rigidities. They argue that the prevalence of such rigidities in Europe has prevented regional wage differences to emerge during the phase of agglomeration, and in consequence have also destroy the long-run competitiveness of peripheral European regions, precluding then the possibility of re-convergence for these regions. In a dynamic framework with endogenous technological change. (Bellone and Maupertuis 2003) show that localized knowledge externalities impede the redispersion of industrial activities even in the presence of labor immobility and perfect wage flexibility. Indeed in this framework, firms are not incited to relocate in the periphery as far as the innovative advantage of the Core compete with the low wage advantage of the Periphery. This model adds another explanation to this paradox. Finally, (Amiti 2004) and (Alonso-Villar 2005) emphasize that the redispersion of industrial activities is more a consequence of a fall in intermediate goods tariff in the former and in intermediate goods transport cost in the latter, than in final goods tariff or transport cost. Secondly, according to econometric analysis, the fall in transport, experienced during these last decades, has been coupled by a decrease in distance of trade (Carrère and Schiff 2005), (Disdier and Head 2008). (Carrère and Schiff 2005) highlighted two explanations to this paradox of distance. First, the distance of trade is more dependent on the components evolution of transfer cost than on the evolution of the global transfer cost. (Disdier and Head 2008) emphasized the increasing importance of distance in trade and review major explanations of this paradox existing in the literature. First of all, we may have underestimated the effect of technical progress. Then, time is becoming more and more important in transport (Hummels 2001) and (Deardorff 2005), especially with the adoption of just-in-time production organization. Finally, this paradox is due to a composition effect in trade, the share of goods sensitive to the distance have increased in trade. From this model, we can precise this composition effect. Indeed, taking into account uncertainty in input-output linkages, intermediate goods borne coordination cost which makes intermediate goods more sensitive to the distance than final goods. Then, the increase of intermediate goods traded over these last decades (Jones and Kierzkowski 2005) makes goods, in general, more sensitive to the distance.

# Appendix

## Simulation

Parameters values used in simulations are defined in the following table:

| Symbols | description | value |
|---|---|---|
| $\alpha$ | the elasticity of production with respect to labor | $\frac{10}{11}$ |
| $\beta$ | the share of income consumer spent in final industrial good | 0.2 |
| $\sigma$ | the elasticity of substitution between different varieties of industrial good | 6 |
| $\mu$ | the share of downstream production spent on intermediate goods | 0.5 |
| $a$ | productivity parameter | $1,2$ |
| $f=\frac{\mu}{\sigma}$ | fixed part of cost | $\frac{1}{12}$ |
| $L_1=L_2$ | dotation of workers per region $\{1,2\}$ | 20 |

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