A Design and Development Model of a MNE: Providing higher Quality vs. Reaching lower Labor Costs

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[1]We acknowledge the financial support of the Direction de l'Espace Rural et des Forêts (DERF) of the Ministère de l'agriculture et de la Pêche for a project entitled "Compétitivité de l'Industrie du Sciage : une Approche Théorique" (Convention 614580.11/02)

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Abstract

This paper settles the boundaries of MNE by looking at the design and developpement process of a final product The question is addressed through the important arbitrage between Worldwide Arm's Length Relations at lower costs but at a poor level of quality vs. costlier product of higher quality through FDI. This arbitrage which contributes to the specific design of the chain of value that a MNE has under control is largely influenced by the proportion of skilled/unskilled workers entering in the production of each input and by the incentive to produce goods of higher quality. These specific characteristics largely explain the various behaviors concerning the location choices and the arbitrage between FDI and WARL.

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Keywords

Vertical limits of a MNE, design and development of a product, fragmentation, location, quality, skilled/unskilled workers

JEL classification : F23 , D21

1 Introduction

The last decades have seen both a spectacular integration of the global economy through trade and a large phenomenon of disintegration of the production units. For instance, Feenstra and Hanson [9] observed, by using U.S input-output tables, that the share of imported intermediates increased from 5,3% of the total U.S intermediate purchases in 1972 to 11,6% in 1990. At the same time, and especially in the last decade, Navaretti and Venables [21] also observe that the inflow from Foreign firm controled by MNE's drastically grew. It reached a rate of 17,7% between 1985-1999 while the worldwide GDP only increased at a rate of 2.5% per year.

This *"downsizing"* effect is often related to vertical *"fragmentation"* of the activities across countries and is therefore hold as an optimal strategy of a Multinational Enterprise (MNE for short) which maximizes the returns of its global *"chain of value"*[1] by locating labor consuming activities in low wage countries. These profit opportunities were initially largely exploited by worldwide organizations like Mattel which generates one and a half billion of Dollars in sales with the Barbie doll or Nike which employs 75000 people in Asia. But there is now an increasing number of medium and small firms which also develop this kind of strategies. For instance Kindy, a french firm whose sales are around 50 millions of Euros pro year, recently decides to stop some of their activities in France and to move them toward Turkey[2]. Even smaller firms locate a part of their activities abroad. The french Haute Couture realizes, for instance, a large part of its activity in Tunisia[3]. But could we really argue that these location decisions are, in these cases, only driven by labor cost considerations ? Wages are surely cheaper in China or in India rather than in Tunisia or in Turkey. So how can we interpret these various strategies ? What are the reasons which prompt firms to split their chain of value worldwide ?

To explore this question, we mainly focus on the decision process of a MNE. From that point of view, we consider that the theory of the MNEs can be view as a part of the theory of the boundaries of the firm (see Turrini-Venables [26]). This problem is clearly related to the question of both vertical (dis)integration (for a comprehensive survey see Markusen [17] [18]) and optimal location choice. This question was often addressed by means of the transaction cost approach or the property right theory[4]. In this paper, we however do not mainly focus on incomplete

[1] Krugman [15] uses the expression *"slicing the value chain"* to characterize this mechanism. Other references to the analysis of global chains of value can be found in Gereffi [10].

[2] Kindy, which is well-known in France for its socks, even closes the factory of Moliens (Oise) in which the story of this firm starts 150 years before under the name of "La Bonneterie Davesne".

[3] In 2000, the sector named "Manufacture of fabric and knitted wear" in Tunisia was composed by 1,658 firms, 1,431 of them exporting all their production mostly to France (35%) and to Italy (22%) (see http://www.tunisianindustry.nat.tn/html/t_indust/inf_sect15.htm). For an other illustration of this situation, the reader is refereed to Audet [3])

[4] In the transaction cost approach, asset specificity typically induces a trade-off between arm's length relation in an incomplete contract setting and less efficient production of intermediates in integrated firms (see for instance

contracts. But, we still maintain a distinction between (vertical) *Foreign Direct Investment* (FDI for short) and *Worldwide Arm's-Length Relations* (WALR for short) by underlining the effect of the quality of the final product on the Design of an organization. This issue is also important for smaller firms like Kindy or french Haute Couture. Since they mainly sell their products in rich countries[5] where quality is valuated, they are also aware that quality contributes to product specificity and to market power. As they *"outsource"*, the headquarters of theses firms have therefore to decide either to co-operate with a foreign downstream firm in order to improve quality but at some costs (investment and bargaining costs), or to mainly take advantage from lower wage abroad from a WALR by producing a good of a lower level of quality.

In order to tackle this trade-off, we depart from a standard two country approach opposing the North to the South[6]. We rather take the point of view of an optimal location approach of a single firm by introducing a continuum of places going, loosely speaking, from the North to the South. The headquarter is located near to the market, that is in the North, and each location is characterized by its *"distance"* to this headquarter : a quantity which measures not only the physical distance but also the development gap or the cultural differences. By introducing this optimal location issue, we therefore become able to understand why a given activity of a chain of value is located closer to the North or to the South and we can, within a same framework, illustrate several strategies (WALR, FDI ...) taking place at different locations.

This framework also enable us to capture the idea that low wage countries, located in less developed areas, are often characterized by a relative scarcity of skilled workers. So even if the labor cost decreases with the distance, the differential between the wages for skilled and unskilled workers often increases. So even if the transportation cost grows proportionally to the distance, we already have under control a first argument which explains the various location strategies of MNEs : high-tech activities should be located closer to the North while labor consuming activities should be moved to the South.

But this does not really introduce a difference between FDI and WALR. This is why we also assume that the headquarter has not only the choice to buy the intermediate good at given location but the possibility to develop a long term relationship with some of her providers in order to improve the quality of the final good by upgrading the qualities of some components[7]. In our paper, this FDI takes the peculiar form of sending engineers from the headquarter to

McLaren [19] or Grossman-Helpman [11]) while, in the property right approach, the emphasis is put on investment-sharing in order to explain Foreign Direct Investment (see Antràs [1]).

[5] By introducing quality, we follow Murphy and Shleifer [20] who argue that high human capital countries have a comparative advantage by producing high quality goods, but are also rich enough to consume these goods. The importance of quality issue is also emphazised by Markusen [16] or Thoenig & Verdier [25].

[6] For studies which take this point of view, the reader is referred for instance to Antràs & Helpman [2], Burda & Dluhosch [4], Deardorff [5], Feenstra & Hanson [8] or Jones & Kierzkowski [12] .

[7] For a seminal reference see Kremer ([13])

some upstream providers with the mission to coordinate the production process[8]. The outcome of this task is decreasing with the distance to the North due to increasing coordination costs. From that point of view, the production of the quality of the final is maid explicit and since the MNE controls this investment, hold-up consideration are ruled-out.

To sum up, we try to explain the various outsourcing strategies by considering both their intent to reduce costs by taking advantage of lower wages abroad and, the necessity to produce final goods of quality in order to keep their market power in their home country.

More precisely, we consider a manufactured good which is assembled from a continuum of intermediate inputs[9] and which is sold on a non-competitive market located in a developed country. The *headquarter* of this firm has the ability to design the organization of this *"global chain of value"* by choosing the *location* where intermediate goods are obtained and the level of *co-operation* with each upstream plant. The first decision simply proceeds from a cost reducing purpose since the headquarter organizes her production worldwide with respect to the ratio of skilled/unskilled labor required by each activity and the relative cost of both factors at each location. While the *co-operation decision* takes into account the nature of the final demand and is motivated by the preservation of market power.

By doing so, we identify three basic strategies : a *WALR strategy* such that the headquarter only takes advantage from lower wages abroad, gives up co-operation and enters into an "arm's-length" relation with an upstream firm, a *Local Direct Investment strategy* (LDI for short) characterized by an investment in Northern countries in order to produce high quality commodities without taking advantage from any lower wages abroad, and finally, a *FDI strategy* which combines the preceding ones. We then show how these strategies are optimally combined within a firm and under which conditions they are selected. The most interesting case is illustrated by an example. It describes a situation in which the headquarter keeps high-tech activities (i.e. requiring a huge amount of skilled workers) in her home country, choose a FDI strategy for, say, medium-tech activities by moving these industries to countries which are not too different, and finally buys *Arm's-Length* in low developed country the inputs requiring a large amount of unskilled labor.

To develop these arguments, we organize our paper in the following way. Section 2 is devoted to a presentation and a discussion of the model under consideration. In section 3, we identify the basic strategies associated to an activity and show how they are optimally combined. Section 4

[8] In the case of the french Haute Couture, one typically observes that (i) Tunis is at one hour a half from Paris by plane (ii) Tunisian is a french speaking stable country. Quality, which is very important in this industry, can therefore be easily controlled.

[9] For the use of a continuum of intermediate inputs see also Dornbush - Fisher - Samuelson [6], Feenstra -Hanson [8] or Sanyal [22].

is devoted to an example which illustrates these different cases. Finally section 5 contains some concluding remarks and further extensions. Proofs are relegated to an appendix.

2 An overview of the model

To illustrate this purpose, we consider a commodity which is sold on a monopolistic market by a downstream firm located in a developed country. The production of this good requires a continuum $[0,1]$ of basic activities each of which enters in the production process with the same weight[10]. These weights are described by a uniform probability distribution μ. Each activity requires both skilled and unskilled labour. We denote by $\lambda(i) \in [0,1]$ the proportion of skill labor used by activity $i \in [0,1]$. The activities are, without loss of generality, ranked from the most to the least demanding one in skilled labor (i.e. $\lambda'(i) < 0$). For simplicity, we also assume that the combination of $\lambda(i)$ and $(1-\lambda(i))$ units of skilled and unskilled labor produces one unit of intermediate good.

2.1 The location and the co-operation choices

The headquarter has the ability to choose the distance $d(i) \geq 0$ at which she locates activity i. Any increase of this distance is viewed as a move to a less developed country.

This location choice is motivated by the search of lower production costs. To capture this idea, we assume that the wages $w_s(d)$ and $w_u(d)$ of the skilled and unskilled workers are decreasing and convex with respect to the distance, i.e. $w_s'(d) < 0$, $w_u^{'}(d) < 0$ and $w_s^{"}(d) \geq 0$, $w_u^{"}(d) \geq 0$, and in order to give some incentives to *"split her chain of value"*, we suppose that $\lim_{d\to 0} w_s^{'}(d) < 0$. Since it is often difficult to find skilled workers in low-wage country, we assume that the wage differential $\Delta w(d) = w_s(d) - w_u(d)$ is increasing with the distance and we suppose that $\Delta w(d) > 0$ (i.e. skilled workers always earn higher wages).

The headquarter however bears, say, a *"transportation cost"* $c_t(d)$ per unit of intermediate product. This cost is increasing and strictly convex i.e. $c_t(0) = 0$, $c_t'(d) > 0$ and $c_t^{"}(d) > 0$. Moreover, in order to create some incentives to "outsource", we say that $\lim_{d\to 0} c_t'(d) = 0$. But we however assume that $\lim_{d\to +\infty} c_t'(d) = +\infty$.

Apart from this location choice, the headquarter also has the ability to develop with each supplier either a short term or a long term relation. In the first case, she applies a WALR strategy by buying a generic component at its competitive price without having a real control

[10] The reader may perhaps be surprised by the assumption of a continuum. One usually thinks at a finite number of activities with different weights. But this is equivalent to considere a continuum of activities with a non-atomless measure or even to look at a partition of $[0,1]$ in which the weight of each element is computed by a Lesbegue measure λ. For applications with a finite number of activities, the reader is refered to Soubeyran -Stahn [23] [24]

of the quality of this component. In the second case, she favours a FDI strategy by starting a co-operation with the upstream firm. We denote by $\mathcal{C} \subset [0,1]$, the subset of activities for which co-operation takes place. In this case, we assume that the headquarter sends, at her own cost, $k(i)$ engineers to the upstream plant in order to adapt the local production process and, by this way, to improve the quality of the component and hence of the final product. We however make the assumption that there is only a proportion $(1-t(d))$ of their working time which is efficient, the other part being lost due to travel time, cultural differences and so on. This proportion $t(d)$ is an increasing and convex function of the distance to the upstream firm. But this last assumption may be in contradiction with the fact that $t(d) \in [0,1]$. This is why we assume[11] that there exists $\bar{d}$ with the property that $\forall d \geq \bar{d}$, $t(d) = 1$ and $\forall d \in \left]0, \bar{d}\right[$, $t'(d) > 0$ and $t"(d) \geq 0$. Finally, we also assume that no working time is wasted when the distance is zero i.e. $t(0) = 0$.

2.2 The design of the product : the different aspects of quality

In our model quality plays a quite central role. As in Murphy and Shleifer [20], we assume that quality is desired by the final consumers located in developed countries, creates market power and is produced by the firms.

Quality is desired. We assume that the consumers are ready to pay for goods of better quality. In order to illustrate this idea, we consider a discrete consumption choice model in which a upgrading quality increases both the number of consumers who are willing to buy the commodity and the range of their reservation prices. More specifically, we introduce a continuum $[0, N(q)]$ of consumers the size $N(q)$ of which increases with the level of quality. If we now identify the index of each agent $i \in [0, N(q)]$ to her reservation price, and if we assume that these prices are uniformly distributed, we can conclude that the demand is given by :

$$D(p,q) = N(q) \cdot \int_p^{N(q)} \frac{1}{N(q)} dx = N(q) - p \tag{1}$$

To simplify the analysis, we even assume that $N(q) = a + b \cdot q$ with $b > 0$.

Quality induces market power. In developed countries, quality is often used as a strategic variable in order to maintain some market power (see, for instance, Thoenig-Verdier [25]) because it contributes to product differentiation. But this means, *a contrario*, that a downstream firm which does not invest in quality nor seeks for lower costs abroad necessarily earns zero profit. Put in other words, we suppose that the consumers are not ready to pay more than the local

[11] The reader should however notice that the existence of this upper bound is a simple consequence of our assumptions. We never make use of that fact in the rest of the paper. More precisely, we do not argue that activities for which co-operation occurs are located closer due to this upper bound.

competitive price if no quality is at hand. So, let us now identify this local competitive price to the unit production cost when no quality is produced and no delocalization occurs. In this case this restriction is fulfilled when the highest reservation price a if no quality is at hand is equal to this cost level i.e. when $a = w_u(0) + (w_s(0) - w_u(0)) \cdot \int_0^1 \lambda(i) d\mu$

Quality is endogeneous and sets up the organization of the MNE. Each upstream activity $i \in \mathcal{C}$ to which the headquarter sends engineers contributes to the production of quality of the final good by improving the quality of some components. To capture this idea, we introduce a *product design function* which summarizes all the activities dedicated to the product and development stage and whose purpose is to define the quality of the final good as outcome of the quality of the components[12]. It renders a commodity characterized by a certain level of quality and therefore by a specific degree of differentiation. To acheive this goal, the headquarter sends at her own cost, i.e. at $w_s(0) \cdot k(i)$, some engineers to some upstream firms in order to begin a long term relation. But, by doing so, she chooses to enter into a specific relation with some of her providers and contributes to the overall design of the boundary of the MNE. One can therefore expect that this relations gives rise to a specific asset and that the two partners initiate a bargaining process in order to share the surplus. To keep the model as simple as possible, we however do not model this bargaining process explicitly, we simply assume that the upstream firm obtains some additional margin m that is taken as given. Since the spatial organization also matter in the definition of the boundary of a MNE, we also assume that only a fraction of the engineer's working time is efficient. The fraction is given by $e(i) = k(i) \cdot (1 - t(d(i)))$ and is decreasing with the distance due to coordination costs (travel cost, cultural differences ...). From that point of view, we say that the quality of the final good aggregates[13] the quality produced in each upstream plants with which co-operation occurs (i.e. for $i \in \mathcal{C}$). In other words, we say that :

$$q = \int_{i \in \mathcal{C}} f(e(i)) \, d\mu \quad \text{with} \quad e(i) = k(i) \cdot (1 - t(d(i))) \tag{2}$$

We also assume that $f(x)$ shares some common features with a production function i.e. $f(0) = 0$, $f'(x) > 0$, $\lim_{x \to 0} f'(x) = +\infty$, $\lim_{x \to +\infty} f'(x) = 0$ and $f"(x) < 0$. Some more technical assumptions are however required. In order to make sure that the optimization problem is well-defined and remains concave, we assume that the elasticity $e_x(f')$ of this marginal production function with respect to x is smaller to $-1/2$ and that $\lim_{x \to 0} x \cdot (f'(x))^2 = +\infty$.

[12] In the managerial literatture, this activity encompasses both the concept development and the supply chain as well as the product design (see for instance Krishnan and Ulrich [14]). We arbitrary reduce these activities to a simple function which captures the contribution of each long term contractor.

[13] Since one unit of each input is required to produce the final good, we also decide to assume that each input contributes to the quality of the final good in a symetric way.

2.3 The MNE design and developement decision problem

Even in this simple setup, we typically observe that an outsourcing decision is a part of a more general problem which covers both the organizational design of the production and the market strategies. It is therefore not really surprising to observe various situations. In fact, the headquarter simultaneously chooses four items : the distance $d(i)$ at which an activity $i \in [0,1]$ is located, the set $\mathcal{C} \subset [0,1]$ of upstream firms which enter in a long term relation with her, the level $k(i)$ of investment that she affects to each $i \in \mathcal{C}$ in order to improve quality, and finally the price p of her final product.

We can, of course, always argue that the choice of the price of the final product is, in some sense, a short term decision. It can be taken once the unit production cost c and the quality q of the final product are known by solving :

$$\pi(q,c) := \max_p D(p,q) \cdot (p-c) \tag{3}$$

It follows that $\pi(q,c) = \frac{1}{4}(N(q)-c)^2$. It however remain to study the long term decisions of this MNE that contribute to the design of her organization i.e. the choice of $\mathcal{C}$, the level of cooperation and the localization of each activity. To proceed, it becomes crucial to know how these decision modify the *cost structure* and the *quality of the final good*.

Let us start with the *cost structure* and let us first remember that an input obtained arm's length is sold at the competitive price which prevails at the location where it is bought. The headquarter therefore gets each unit of input $i \in [0,1] \setminus \mathcal{C}$ at its local production cost and supports a transportation cost covering its delivery. Since each unit of input i requires a combination $(\lambda(i), 1-\lambda(i))$ of respectively skilled and unskilled labor and that one unit of each input is required to produce one unit of the final output, the cost generated by activity i per unit of final product is thus given by :

$$\forall i \in [0,1] \setminus \mathcal{C}, \quad \rho(d(i), \lambda(i)) := w_s(d(i)) \cdot \lambda(i) + w_u(d(i)) \cdot (1-\lambda(i)) + c_t(d(i)) \tag{4}$$

If cooperation occurs, i.e. for any activity $i \in \mathcal{C}$, the story is somewhat different. Since she also sends engineers to the upstream firm and support a bargaining cost, we can conclude that the cost of one unit of input $i \in \mathcal{C}$ is given by :

$$\forall i \in \mathcal{C}, \quad \rho_{\mathcal{C}}(d(i), \lambda(i)) := \rho(d(i), \lambda(i)) + w_s(0)\, k(i) + m \tag{5}$$

If we now aggregate these costs over all activities, we obtain the *unit production cost* of the downstream firm. This quantity is given by :

$$c\left(d(\cdot), k(\cdot), \mathcal{C}\right) := \int_0^1 \rho\left(d(i), \lambda(i)\right) d\mu + \int_{i\in\mathcal{C}} \left(w_s\left(0\right) k(i) + m\right) d\mu \tag{6}$$

This is typically a functional because it takes as arguments the functions $d(\cdot)$ and $k(\cdot)$ which respectively associates to each activity $i \in [0,1]$ a location and investment level and, from that point of view, summarize the *Design model of the organization* of the MME.

Now let us remember that the *quality of the final good* is given by

$$q\left(d(\cdot), k(\cdot), \mathcal{C}\right) := \int_{i\in\mathcal{C}} f\left(e(i)\right) d\mu \text{ with } e(i) = k(i)\cdot\left(1 - t\left(d(i)\right)\right) \tag{7}$$

We can therefore conclude by equations (3),(6) and (7) that the profit of the headquarter is given by :

$$\Pi\left(d(\cdot), k(\cdot), \mathcal{C}\right) := \pi\left(q\left(d(\cdot), k(\cdot), \mathcal{C}\right), c\left(d(\cdot), k(\cdot), \mathcal{C}\right)\right) \tag{8}$$

The basic decision problem of this firm is therefore summarized by :

$$\max_{\mathcal{C}\subset[0,1]} \left\{ \max_{\left((k(i))_{i\in\mathcal{C}}, (d(i))_{i\in[0,1]}\right)} \Pi\left(d(\cdot), k(\cdot), \mathcal{C}\right) \right\} \tag{9}$$

This general problem can nevertheless be slightly simplified owing to the peculiar structure of our model. If fact, we know that $\pi(q,c) = \frac{1}{4}\left(N(q) - c\right)^2$ and that $N(q) = a + b\cdot q$. If we denote, for all $i \in \mathcal{C}$, the returns of the investment in quality by :

$$R\left(k(i), d(i)\right) := b\cdot f\left[e(i)\right] - w_s\left(0\right)\cdot k(i) - m \tag{10}$$

we observe that this decision problem can be written as :

$$\max_{\mathcal{C}\subset[0,1]} \frac{1}{4}\left(a + \int_{i\in\mathcal{C}} \left(\max_{(k(i),d(i))} R\left(k(i), d(i)\right) - \rho\left(d(i), \lambda(i)\right)\right) d\mu - \int_{i\in[0,1]\setminus\mathcal{C}} \left(\min_{d(i)} \rho\left(d(i), \lambda(i)\right)\right) d\mu\right)^2$$

3 The optimal strategy

This last expression of the decision problem is quite interesting. It tells us that we can study the problem step-wise. In fact, we first seek for the best location strategy by assuming that no investment occurs at all. This renders not only the best WALR strategy but also the lowest cost that can be achieved per activity. We then consider the opposite case by forcing the investment levels to be strictly positive. Since, the headquarter chooses, in this case, both the distance and the investment per activity, we can discuss the relative advantages of Local Direct Investment (LDI) *versus* FDI. But we also obtain the gain per activity of a strategy characterized by the production of goods of higher quality. It therefore remains in a last step to compare, for each activity, the returns of the production of quality to the opportunity cost induced by a less optimal location (i.e. a higher cost than the lowest one). This renders the set $\mathcal{C}$ of activity for which co-operation occurs.

3.1 WALRs : the effect of skilled workers on location

In this subsection, we essentially draw attention to the effect of the proportion $\lambda(i)$ of skilled workers entering in the production of input i at a given location. Since co-operation is not allowed, the headquarter simply estimates the gain from producing abroad and puts this profit into balance with her transportation cost. The best location $d^W(i)$ therefore coincides to a situation in which the marginal transportation cost per unit of input is equal to the marginal outsourcing gain per unit of input. If one has in mind that each activity mixes both skilled and unskilled workers in a different proportion $\lambda(i)$, one can assert that :

Proposition 1 *Suppose that no investment in quality occurs, then there exists, for each activity* $i \in [0,1]$, *a unique optimal location* $d^W(i)$ *which solves :*

$$c_t'\left(d^W(i)\right) = -\left(w_s'\left(d^W(i)\right) \cdot \lambda(i) + w_u'\left(d^W(i)\right) \cdot (1-\lambda(i))\right) \tag{11}$$

We identify, for latter use, this choice to a WARL strategy

Let us now add to the story the fact that it is more difficult to find skilled workers in low-wage countries. This means that for any move to less developed countries, the wage differential between skilled and unskilled labor forces increases (i.e. $(\Delta w(d))' > 0$). Under this harmless restriction, we can conclude that :

Proposition 2 *If no co-operation occurs then :*

(a) *There is a tendency to keep activities which require more skilled workers closer to the developed countries and reciprocally to "delocate" those consuming more unskilled workers to low-wage countries. This means that the optimal distance* $d^W(i)$ *at which activity* i *is located decreases with the proportion* $\lambda(i)$ *of skilled workers entering into the production of input* i.

(b) *The lowest cost* $\rho^W(i) = \min_{d(i)\geq 0} \rho(d(i), \lambda(i))$ *that can be obtained for activity* i *decreases with the proportion of skilled workers.*

(c) *As a consequence of (a), (b) and the fact that* $\lambda'(i) < 0$, *we observe that* $\left(d^W(i)\right)' > 0$ *and that* $\left(\rho^W(i)\right)' = \Delta w\left(d^W(i)\right) \cdot \lambda'(i) < 0$

3.2 Co-operation : LDI vs. FDI

If co-operation occurs, the problem of the headquarter is more complicated. She has not only to decide at which distance[14] $d^I(i)$ she wishes to locate a given activity but she also has to choose a level of investment $k(i)$ for each activity. This decision must therefore take into account both the decreasing returns of this investment with respect to the distance and the ability to take advantage from lower wages abroad. For an activity i, this strategy $\left(k^I(i), d^I(i)\right)$ therefore solves :

$$\left(k^I(i), d^I(i)\right) \in \underset{k>0,d\geq 0}{\arg\max} R\left(k(i), d(i)\right) - \rho\left(d(i), \lambda(i)\right) \tag{12}$$

The existence of a solution to this optimization problem is less obvious. The technical assumptions introduced in section 2 are now required. In fact, if one assumes that the elasticity $e_x(f')$ of the marginal quality production function is smaller then $-1/2$ and that $\lim_{x\to 0}\left(f'(x)\right)^2 \cdot x = +\infty$[15], we can show that this program admits a unique solution (see proof of proposition 3).

Apart from this technical but necessary issue, the reader also notices that this program gives rise to two different configurations for a given activity $i \in [0,1]$. Either the firm really invests abroad (i.e. $k^I(i) > 0$ and $d^I(i) > 0$) or she prefers to keep this activity in her home country (i.e. $k^I(i) > 0$ and $d^I(i) = 0$). This last situation typically occurs if the non-negativity constrain $d \geq 0$ is binding. This happens if, at the North optimal investment level, the marginal increase of the monitoring cost due to "delocation" and which is measured by $\Delta MC = w_s(0) \cdot (f')^{-1}\left(\frac{w_s(0)}{b}\right) \cdot t'(0)$ is higher than the marginal gain obtained from the labor cost cut i.e. $\Delta LC(i) = \left|\frac{\partial \rho\left(d^I(0), \lambda(i)\right)}{\partial d}\right|$. We can therefore state :

Proposition 3 *Under the assumption that co-operation occurs, there exists, for each activity* $i \in [0,1]$, *a unique optimal location* $d^I(i) \geq 0$ *and a unique optimal investment level* $k^I(i) > 0$ *which solves (12)*[16]*. Two different strategies are however observed . If* $\Delta MC \geq \Delta LC(i)$*, the headquarter selects a Local Direct Investment (LDI) strategy by entering in a long term relation with firms located at* $d^I(i) = 0$ *while, in the opposite case, this firms prefers a FDI strategy (i.e.* $d^I(i) > 0$*).*

We can even go a step further into the characterization of these strategies. In fact, let us

[14] The upper-script I stands for Investment. Moreover if $d^I(i) = 0$ we typically deal with a LDI behavior, in the other case FDI occurs.

[15] This assumption capture two ideas. First we assume that the production function is relatively concave in the sense that "the index of relative risk aversion" is greater then 1/2. Secondly, we want to make sure that there is an incentive to invest because $\lim_{x\to 0}\left(f'(x)\right)^2 \cdot x = +\infty$ implies for instance that $\lim_{x\to 0}\left(f'(x)\right) = +\infty$.

[16] *A more technical description of both solutions can be found in the Appendix.*

observe, by computation that

$$\Delta LC(i) = \left| \frac{\partial \rho \left(d^I(0), \lambda(i) \right)}{\partial d} \right| = - \left(w_s' (0) \cdot \lambda(i) + w_u' (0) \cdot (1 - \lambda(i)) \right) \tag{13}$$

and let us remember that the wage differential between skilled and unskilled labor is an increasing function. We can therefore state that

$$-\frac{\partial^2 \rho (0, \lambda)}{\partial d \partial \lambda} = - \left(w_s (0) - w_u (0) \right)' < 0 \tag{14}$$

Since we have ranked the different activities by decreasing the required proportion of skilled labor (i.e. $\lambda'(i) < 0$), we can assert that the gain related to the labor cost cut is increasing with the index i of the activity i.e. $\frac{d(\Delta LC(i))}{di} > 0$. It simply remains first to observe that the marginal increase of the monitoring cost, i.e. ΔMC, is independant of this index and secondly to conclude that :

Proposition 4 *Under the assumption that co-operation occurs for each activity, three different cases can be observed :*

(a) *If $\Delta MC \geq \Delta LC(1)$ then all activities are kept in the home country because even for the activity requiring the smallest proportion of skilled workers the marginal increase of the monitoring costs is not covered by the marginal labor cost cut. We refer to this case as a **Pure LDI** situation*

(b) *If $\Delta MC \leq \Delta LC(0)$ then no activity is kept in the home country because even for the activity requiring the largest proportion of skilled workers the marginal labor cut always compensates the additional monitoring costs. We call this case a **Pure FDI** situation.*

(c) *If $\Delta LC(0) < \Delta MC < \Delta LC(1)$, then there exists a unique activity, say $i_{L/F} \in]0, 1[$, (or a proportion of skilled workers $\lambda(i_{L/F})$) with the property that any activity $i \leq i_{L/F}$ is kept into the home country while the others are located in lower wage countries. We refer later to this situation as a **L/F DI** case.*

This last proposition also tells us that the production of quality refrains the incentives to move some activities abroad. In fact, a part of the gain of the cost labor cut helps to cover the increasing monitoring cost. We can therefore expect that :

Proposition 5 *If co-operation occurs, then :*

(a) *There is a natural tendency to locate an activity closer to developed countries with respect to a situation in which no cooperation occurs i.e. $\forall i \in [0, 1]$, $d^I(i) < d^W(i)$.*

(b) *The distance at which an activity is located remains however non increasing with the proportion of skilled workers. High-skilled activities are again kept closer to the downstream* *firm i.e.* $\frac{d^I(i)}{di} \geq 0$

To conclude this subsection and to prepare the comparison to a WALR situation, it remains to characterize the returns generated by each activity under the assumption that co-operation takes place. By the envelop theorem, we can assert that :

Proposition 6 *Under the assumption that co-operation occurs, the optimal contribution of activity* i *to the global profit i.e. the quantity* $v^I(i) = \max_{(k,d)} R(k(i), d(i)) - \rho(d(i), \lambda(i))$ *is an increasing function of* i*. More precisely* $\left(v^I(i)\right)' = -\Delta w\left(d^I(i)\right) \cdot \lambda'(i) > 0$

3.3 WARL vs. co-operation

This last subsection is dedicated to the design of the global chain of value of the final commodity, or in other words to the arbitrage between the two preceding situations. This one can be summarized as follow : for a given activity which combines both skilled and unskilled labor is it more interesting to develop a long term relation which improves the quality of the final product at a higher labor cost or it is more attractive to take advantage from an optimal cost reducing strategy by entering in a short term relation without improving quality ?

The comparison of both situation is now quite easy. We exactly know the returns of a long term relation : they are given by $R\left(k^I(i), d^I(i)\right)$ for activity i. We are also aware of the consequence of a less optimal location with respect to a short term relation. This opportunity cost is typically measured by $\rho\left(d^I(i), \lambda(i)\right) - \rho\left(d^W(i), \lambda(i)\right) \geq 0$. We can therefore conclude that the set $\mathcal{C}$ of activities for which investment occurs is given by :

$$\mathcal{C} = \left\{i \in [0,1] : R\left(k^I(i), d^I(i)\right) \geq \rho\left(d^I(i), \lambda(i)\right) - \rho\left(d^W(i), \lambda(i)\right)\right\} \quad (15)$$

In other words, investment takes place if $v^I(i) + \rho^W(i) \geq 0$. By proposition 2(c) and proposition 6, we even observe that :

$$\frac{dv^I(i)}{di} + \frac{d\rho^W(i)}{di} = \left(-\Delta w\left(d^I(i)\right) + \Delta w\left(d^W(i)\right)\right) \cdot \lambda'(i) \quad (16)$$

Moreover, we know by proposition 5(a) that $d^I(i) \leq d^W(i)$. Since the wage differential $\Delta w(d)$ is an increasing function and $\lambda'(i) < 0$, we can also assert that $\frac{d\pi^I(i)}{di} + \frac{d\rho^W(i)}{di} \leq 0$. It is now a matter of consequence to observe that :

Proposition 7 *The following assertions hold :*

(a) *If the returns of the investment in quality of the activity employing the highest proportion of skilled workers does not cover the opportunity cost of a less optimal location i.e.* $v^I(0) +$

$\rho^W(0) < 0$, then no co-operation occurs at all, i.e. $\mathcal{C} = \varnothing$. We refer to this case as a ***pure WARL*** *situation.*

(b) *Reciprocally if the reversed inequality holds for the lowest proportion of skilled workers, i.e. $v^I(1) + \rho^W(1) > 0$, the headquarter begins a co-operation process with each upstream firm, i.e. $\mathcal{C} = [0, 1]$. This* ***pure co-op****eration case can however take the form of a local or a foreign direct investment.*

(c) *If none of the two preceding conditions are fulfilled, there exists a unique activity $i_{C/W}$ with the property that $\mathcal{C} = \left[0, i_{C/W}\right]$. This means that the activities requiring a large proportion of skilled workers only enter into a co-operation process. We refer to this case a* ***C/W situation***

After these preliminary remarks, let us now summarize the various designs of a chain of value of a given product. As announced in the introduction, we basically identify three types of strategy that can be associated to a given activity $i \in [0, 1]$:

- **WALR**. In this case, the headquarter simply takes advantage from lower wages abroad, gives up co-operation and enters into an "arm's-length" relationship with the upstream firm. In other words, she chooses $d^W(i)$ of proposition 1 and sets $k^W(i) = 0$.
- **LDI**. In this situation, the headquarter largely invests into this activity in order to improve the quality of the final product but does not take advantage from lower wages abroad. She plays $d^I(i) = 0$ and $k^I(i) = b \cdot (f')^{-1}\left(\frac{w_s(0)}{b}\right)$.
- **FDI**. Here the headquarter, on the one hand, accepts increasing adjustment costs in order to benefit from lower wage abroad without fully taking advantage from this opportunity, but, on the other hand, she benefits from a final product of higher quality. She chooses $0 < d^I(i) \leq d^W(i)$ and $k(i)$ as defined in proposition 3.

The *Global Design* of the worldwide organization of the given firm simply follows from an optimal arrangement of this basic activities by taking into account the arbitrage between local and worldwide investment (see proposition 4) and the choice between a long or a short term relation (see proposition 7). More precisely, we can assert that :

Proposition 8 *The various outsourcing strategies of small firms with respect to the worldwide market are depicted in the following table :*

	pure co-op	C/W situation	pure WALR
pure LDI	LDI for all $i \in [0,1]$	- LDI for $i \in [0, i_{C/W}]$ - WALR for $i \in]i_{C/W}, 1]$	WALR for all $i \in [0,1]$
L/F DI	- LDI if $i \in [0, i_{L/F}]$ - FDI if $i \in]i_{L/F}, 1]$	- if $i_{C/W} \leq i_{L/F}$ $\begin{cases} \text{LDI for } i \in [0, i_{C/W}] \\ \text{WALR for } i \in]i_1, 1] \end{cases}$ - if $i_{C/W} > i_{L/F}$ $\begin{cases} \text{LDI for } i \in [0, i_{L/F}] \\ \text{FDI for } i \in]i_{L/F}, i_1] \\ \text{WALR } i \in]i_{C/W}, 1] \end{cases}$	WALR for all $i \in [0,1]$
pure FDI	FDI for all $i \in [0,1]$	- FDI for $i \in [0, i_{C/W}]$ - WALR for $i \in]i_{C/W}, 1]$	WALR for all $i \in [0,1]$

4 A illustrative example

This section is dedicated to an example which illustrates our model and lays emphasis on our basic trade-off between higher quality and lower costs. This is why we explicitly introduce two parameters. The first one α stands for a cost labor cut. In fact we assume that the wages are given by $w_s(d) = 8 - \alpha d$ and $w_u(d) = 7 - \left(\frac{3}{2} + \alpha\right) \cdot d$ with $\alpha \in [0,1]$. Both wages therefore decrease with α at each location, but the wage differential $\Delta w = 1 + \frac{3}{2}d$ remains unchanged. The quantity α is therefore a real cost cut proportional to the distance and independent of the activity under consideration. The second parameter β gives us the opportunity to increase the incentives to produce quality. More precisely, we suppose that the number of potential buyers of the final good is given $N(q) = 7.5 + \sqrt{\beta} \cdot q$ with $\beta \in [1,4]$.

Concerning the rest of the model, we assume that (i) the proportion of skilled workers in each activity $i \in [0,1]$ linearly decreases from 1 to 0, i.e. $\lambda(i) = 1 - i$, (ii) the production of quality is captured by $f(e) = 4 \cdot \sqrt{e}$, (iii) the proportion of lost working time is described by $t(d) = d$, (iv) the transportation costs are quadratic, i.e. $c_t(d) = \frac{1}{2} \cdot d^2$ and (v) the margin taken by providers which cooperate are set to zero.

Within this setup, our basic problem becomes [17] :

$$\max_{\mathcal{C} \subset [0,1]} \frac{1}{4} \left(\int_{i \in \mathcal{C}} \left(7.5 + \max_{(k(i),d(i)) \geq 0} R\left(k(i), d(i)\right) - \rho\left(d(i), i\right) \right) d\mu + \int_{i \in \mathcal{C}} \left(7.5 - \min_{d(i) \geq 0} \rho\left(d(i), i\right) \right) d\mu \right)^2$$

with

$$\begin{cases} R\left(k(i), d(i)\right) = 4\sqrt{\beta}\sqrt{k(i)\left(1 - d(i)\right)} - 8k(i) \\ \text{and} \\ \rho\left(d(i), i\right) = (8 - i) - d(i)\left(\frac{3}{2}i + \alpha\right) + \frac{1}{2}d(i)^2 \end{cases}$$

[17] The reader may perhaps object that some variables like the wages are not subject to non-negativity constrains. This is without consequenses because we have designed the example such that this never occurs at the optimum. Hence one can always replace these equations by new ones where one simply takes the maximum between zero and these quantities.

So let us first solve it by applying the method depicted in section 3.

Let us start with a WALR strategy. This one solves $\min_{d(i)} \rho(d(i), i)$ for each activity $i \in [0,1]$. It is therefore a matter of computation to observe that :

$$d^W(i) = \frac{3}{2}i + \alpha \quad \text{and} \quad \rho^W(i) = (8-i) - \frac{1}{2}\left(\frac{3}{2}i + \alpha\right)^2 \tag{17}$$

Let us now consider the strategies in which investment occurs. This strategy, for each activity $i \in [0,1]$, solves $\max_{(k(i),d(i))\geq 0} (R(k(i), d(i)) - \rho(d(i), i))$ and we know, by the Kuhn-Tucker conditions, that two regimes occur : the LDI and the FDI case. A routine computation leads to the conclusion that :

$$k^{LDI}(i) = \frac{\beta}{16} \quad \text{and} \quad v^{LDI}(i) = \frac{\beta}{2} - (8-i) \tag{18}$$

and that :

$$\begin{cases} d^{FDI}(i) = \frac{3}{2}i + \alpha - \frac{\beta}{2} \quad , \quad k^{FDI}(i) = \frac{1}{16}\beta\left(1 - \left(\frac{3}{2}i + \alpha - \frac{\beta}{2}\right)\right) \\ \text{and,} \quad v^{FDI}(i) = \frac{\beta}{2} - (8-i) + \frac{1}{2}\left(\frac{3}{2}i + \alpha - \frac{\beta}{2}\right)^2 \end{cases} \tag{19}$$

Moreover we know, by proposition 4, that LDI occurs as long as :

$$i \leq i_{L/F} = \max\left\{\min\left\{\frac{2}{3}\left(\frac{\beta}{2} - \alpha\right), 1\right\}, 0\right\} \tag{20}$$

while FDI takes place for $i > i_{L/F}$. We can therefore summarize these two cases in the following way :

$$\begin{cases} d^I(i) = \max\left\{\frac{3}{2}i + \alpha - \frac{\beta}{2}, 0\right\} \text{ and } k^I(i) = \frac{1}{16}\beta\left(1 - d^I(i)\right) \\ v^I(i) = \frac{\beta}{2} - (8-i) + \frac{1}{2}\left(d^I(i)\right)^2 \end{cases} \tag{21}$$

It now simply remains to compare the returns of a WALR and co-operation strategy for each activity. This can be done by comparing $v^I(i) + \rho^W(i)$ to 0. But we also know that this last quantity decreases with i. It therefore remains to identify the activity $i_{C/W}$ for which a switch occurs from co-operation to WALR. So let us first observe that a switch from LDI to WALR never takes place in our case. In fact it happens if $\beta - \left(\frac{3}{2}i_{C/W} + \alpha\right)^2 = 0$, but this implies, since $\beta \in [1,4]$, that $i_{C/W} = \frac{2}{3}\left(\sqrt{\beta} - \alpha\right) \geq i_{L/F}$, a contradiction. We can therefore assert that $i_{C/W}$ is given by $\frac{\beta}{2} + \frac{1}{2}\left(d^I(i_{C/W})\right)^2 - \frac{1}{2}\left(d^W(i_{C/W})\right)^2 = 0$. After some routine computations, we obtain :

$$i_{C/W} = \max\left\{\min\left\{\frac{2}{3}\left(1 - \alpha + \frac{\beta}{4}\right), 1\right\}, 0\right\} \tag{22}$$

and it is a matter of fact to observe that $i_{C/W} \geq i_{L/F}$. By mixing all these results, we can finally conclude that the optimal strategy is given by

$$(d^*(i),k^*(i)) = \begin{cases} \left(0, \frac{\beta}{16}\right) \text{ for } 0 \leq i \leq i_{L/F} \\ \left(\frac{3}{2}i+\alpha-\frac{\beta}{2}, \frac{1}{16}\beta\left(1-\left(\frac{3}{2}i+\alpha-\frac{\beta}{2}\right)\right)\right) \text{ for } i_{L/F} \leq i \leq i_{C/W} \\ \left(\frac{3}{2}i+\alpha, 0\right) \text{ for } i_{C/W} \leq i \leq 1 \end{cases} \tag{23}$$

and that the contribution $V(i)$ of each activity to the profit (i.e. $\pi = \int_0^1 V(i)di$) is given by :

$$V(i) = -0,5 + i + \mathbb{I}_{[0,i_{F/C}]}\left(\frac{\beta}{2} + \frac{1}{2}\mathbb{I}_{[i_{L/F},i_{F/C}]}\left(\frac{3}{2}i+\alpha-\frac{\beta}{2}\right)^2\right) + \frac{1}{2}\mathbb{I}_{[i_{F/C},1]}\left(\frac{3}{2}i+\alpha\right)^2 \tag{24}$$

where $\mathbb{I}_A = 1$ if $i \in A$ and $\mathbb{I}_A = 0$ if $i \notin A$

This example typically illustrates the two forces which are at work in a location choice and which give rise to three kinds of strategies. There is, on the one hand, a strong incentive to keep say high-tech industries (using a large amount of skilled workers) in developed countries because (i) they largely contribute to the quality of the final good and (ii) the cost cut induced by a delocalization in southern countries is not significant. On the other hand, the headquarters of these firm also have a strong incentive to move low-tech industries abroad in order to benefit from lower labor cost. This opposition however induces a third strategy characterizing the "medium-tech" industries which combines both delocalization and co-operation. This is why (see equation 23) the distance at which these activities is located increases with the cost cut index but decreases with the incentive to produce quality, while at the same time the level of investment decreases with α and increases with β.

This situation is perfectly illustrated if we set $\alpha = 1/2$ and $\beta = 2$. In this case, the set of activities is split into three subsets of the same size for which LDI, FDI and WARL are respectively the optimal strategies. The optimal distances and investment level are given by :

figure1

while the contribution to the profit of each activity are depicted by :

figure 2

The reader even notices that the size and the kind of these medium-tech activities is even endogenous. This is quite significant in this example. In fact if $0 < i_{L/F} \leq i_{F/W} < 1$, one observes that $\left(i_{F/W} - i_{L/F}\right) = 1 - \frac{\beta}{2}$. Even if there are some boundary effects related to the fact that $i \in [0,1]$, we can therefore conclude, as it is illustrated in the next figure, that the size of these activities decreases with β. This result is however not really surprising. If the incentive to produce good of high quality increases, the headquarter is willing to invest more and to increase her control on the production process of the upstream provider. One can therefore expect that she would keep more activities in the home country, especially, those wich require higher levels of skilled workers.

figure 3

This last figure also tells us that the kind of activities which are devoted to both delocalization and co-operation must be related to the gain from the labor cost cut. To be more precise, if the gain from delocalization increases there is a strong incentive to develop a WALR using activities which require a higher fraction of skilled worker. This means that $i_{F/W}$ decreases as the labor cost cut increases. This is typically illustrated in the next figures.

figure 4

5 Concluding remarks

In this paper, we proposed a model which empahsaize the design and development aspect of product in order to understand the boundary and the spatial organization of a MME balancing between ajustment costs to manage quality and lower wages abroad. This gave us the opportunity to explain the various behaviors of firms which decide to fragment their production process across countries and which are small with respect to the worldwide market. The basic arguments were found in the study of the optimal behavior of these firms with respect to the design of the global chain of value of their product. We assumed that the headquarter of each firm had the ability to choose for each activity within her chain of value both a location and a level of co-operation. In the first case, she benefits from lower wages abroad mainly for unskilled workers while in the second case she improves the quality of her final product at some increasing monitoring costs with respect to the distance. From that point of view, we argued that the various behaviors were explained by attributes which are specific to each chain of value. We especially put an emphasis on the distribution of skilled workers across activities and on the incentives to produce goods of higher quality.

In order to develop this argument, we identify three basic strategies which can be applied to a given activity. The first one is a WALR strategy. In this case, the headquarter simply takes advantage form lower wages abroad, gives up co-operation and enter in an "arm's-length" relation with the upstream firm. We opposed to this behavior a LDI strategy. If this situation occurs, this activity contributes to the production of quality but does not take advantage from lower wages abroad. The last basic strategy was simply a combination of the previous ones i.e. a FDI strategy. In this case the headquarter accepts to bear higher control costs in order to benefit from lower wage. Within this setting, we explained the different observed outsourcing behaviors by different combinations of these basic strategies along the activities which compose the global chain of value of a given commodity. More precisely we argued that this optimal choice relied not only on informations which are common to all firms like the wage structure or the transportation costs but also on peculiar characteristics of the chain of value under consideration like the distribution of skilled workers across the different activities or the importance attributed to the quality of the final commodity.

We can therefore conclude that our model of an MNE illustrates several stylized fact. First we show that if FDI occurs this investments concentrates in skill-intensive industries while unskill-intensive activities are simply "outsourced". Secondly we observed that these investments go prodominantly to more advanced countries i.e. the swap from a WARL to a FDI strategy always induces a drastic reduction of the distance at which the activity is located. Thirdly, we implicitely assume that the FDI strategies originate predominantly from advanced countries because, in this areas, quality is valuated by the final consumers and it is in fact the design of products of higher quality which induces FDI behaviors.

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APPENDIX

A Proof of proposition 1

The proof of this fact is quite obvious. If no investment occurs, the headquarter locates each activity at a distance which minimizes her production cost i.e. at a distance d^W which solves[18] $\min_{d \geq 0} \rho(\lambda, d)$. By computation, we observe that :

$$\frac{\partial \rho(d,\lambda)}{\partial d} = w_s'(d) \cdot \lambda + w_u'(d) \cdot (1-\lambda) + c_t'(d) = 0 \tag{25}$$

and

$$\frac{\partial^2 \rho(d,\lambda)}{\partial d^2} = w_s''(d) \cdot \lambda + w_u''(d) \cdot (1-\lambda) + c_t''(d) \tag{26}$$

Because $w_s''(d) \geq 0$, $w_u''(d) \geq 0$ and $c_t''(d) > 0$, it is immediate by equation (26) that $\frac{\partial^2 \rho(d,\lambda)}{\partial d^2} > 0$. Equation (25) is therefore both a necessary and a sufficient condition for optimality. Let us now remember that $(\Delta w(d))' = (w_s'(d) - w_u'(d)) > 0$ and $\lambda \leq 1$, it follows that :

$$\forall \lambda \in [0,1], \quad \frac{\partial \rho(d,\lambda)}{\partial d} = \left(w_s'(d) - w_u'(d)\right) \cdot \lambda + w_u'(d) + c_t'(d) \leq w_s'(d) + c_t'(d) \tag{27}$$

Because $\lambda \geq 0$ and $(\Delta w(d))' > 0$, we can also assert that :

$$\forall \lambda \in [0,1], \quad \frac{\partial \rho(d,\lambda)}{\partial d} \geq w_u'(d) + c_t'(d) \tag{28}$$

But we have assumed that $\lim_{d\to 0} c_t'(d) = 0$ and $\lim_{d \to 0} w_s'(d) < 0$, inequality (27) therefore implies that :

$$\forall \lambda \in [0,1], \quad \lim_{d\to 0} \frac{\partial \rho(d,\lambda)}{\partial d} \leq \lim_{d \to 0} w_s'(d) < 0 \tag{29}$$

[18] In order to simplify the notations, we neglect the reference to activity i as long as it is not crucial for the comprehension.

Moreover, we know that $w_u(d)$ is decreasing and convex, hence $\lim_{d\to+\infty} w_u'(d)$ is finite. If one has in mind that $\lim_{d\to+\infty} c_t'(d) = +\infty$, inequality (28) induces that :

$$\forall\lambda \in [0,1], \quad \lim_{d\to+\infty} \frac{\partial\rho(d,\lambda)}{\partial d} \geq \lim_{d\to+\infty} w_u'(d) + \lim_{d\to+\infty} c'(d) > 0 \tag{30}$$

By the intermediate value theorem, it follows that there exists a d^W with the property that $\forall\lambda \in [0,1]$, $\frac{\partial\rho(d^W,\lambda)}{\partial d} = 0$. Moreover because $\frac{\partial^2\rho(d,\lambda)}{\partial d^2} > 0$ this quantity is unique. ■

B Proof of proposition 2

(a) By applying the implicit function theorem to equation (25) and because $(\Delta w(d))' > 0$, we observe that :

$$\frac{d\left(d^W\right)}{d\lambda} = -\frac{w_s'(d) - w_u'(d)}{c_t"(d(i)) + (w_s"(d)\cdot\lambda + w_u"(d)\cdot(1-\lambda))} = -\frac{(\Delta w(d))'}{\partial^2_\lambda\rho(d,\lambda)} < 0 \tag{31}$$

(b) By the envelop theorem, and because $\Delta w(d) > 0$, we can assert that :

$$\frac{d\min\rho(d,\lambda)}{d\lambda} = \left.\frac{\partial\rho(d,\lambda)}{\partial\lambda}\right|_{d=d^{ST}} = w_s\left(d^W\right) - w_u\left(d^W\right) = \Delta w(d^W) > 0 \tag{32}$$

(c) If we have in mind that $\lambda'(i) < 0$, it follows that :

$$\begin{cases} \left(d^W(i)\right)' = -\dfrac{(\Delta w(d))'}{\partial^2_\lambda\rho(d,\lambda)}\cdot\lambda'(i) > 0 \\ \\ \left(c^W(i)\right)' = (\Delta w(d))\cdot\lambda'(i) < 0 \end{cases} \tag{33}$$

■

C Proof of proposition 3

The proof of this proposition proceeds in 3 steps. We first make sure that we deal with a strictly concave optimization problem under the restriction that $e_e(f') \leq -1/2$. In a second step, we quickly study the first order Kuhn-Tucker conditions in order to identify the two regimes. Finally we make sure that a solution exists in both cases.

Step 1 : *For each couple (k,d), we deal with a strictly concave maximization problem*
Let us first remember that we have to find $\left(k^I(i), d^I(i)\right) \in \arg\max_{(k,d)\in\mathbb{R}_+\times[0,\bar{d}]} R(k,d) - \rho(d,\lambda)$. By the proof of proposition 1, is is immediate that $\rho(d,\lambda)$ is strictly convex with respect to d. Seeing that the cost of an investment is linear in k, it simply remains to check that $f(k,d)$ is concave with respect to (k,d). By computation, we obtain :

$$\partial^2 f = \begin{bmatrix} f"(e)\cdot(1-t(d))^2 & (-t'(d))\cdot(f"(e)\cdot x + f'(e)) \\ (-t'(d))\cdot(f"(e)\cdot x + f'(e)) & f"(e)\cdot k^2\cdot(t'(d))^2 + f'(e)\cdot k\cdot(-t"(d)) \end{bmatrix} \tag{34}$$

with $e = k\cdot(1-t(d))$. It is immediate that $f"(e)\cdot(1-t(d))^2 < 0$ because $f"(e) < 0$. In order to make sure that this matrix is negative definite, it remains to prove that $\det\left(\partial^2 f\right) \geq 0$. By computation :

$$\det\left(\partial^2 f\right) = \underbrace{f"(e)\cdot f'(e)\cdot e\cdot\left(t'(d)\right)^2}_{\leq 0}\cdot\left(\underbrace{-\frac{(1-t(d))\cdot(t"(d))}{(t'(d))^2}}_{\leq 0} + \underbrace{\left(-2-\frac{1}{e_e(f')}\right)}_{\leq 0}\right) \geq 0 \tag{35}$$

because $f(e)$ is increasing and concave, $t(d)$ is increasing and convex, and $e_e(f') \leq -1/2$.

Step 2 : *The first order conditions*

Let us assume that $k > 0$ otherwise we are back to a WALR strategy. Under this restriction, it is a matter of fact to observe that $d < \bar{d}$, otherwise there is an opportunity to increase the profit by decreasing d because $\forall k > 0$, $\lim_{d\to\bar{d}} f'(k\cdot(1-t(d))) = +\infty$. But we cannot exclude the case in which $d = 0$. This occurs if there is a strong incentive to keep some activities close to the downstream firm. From that point of view, we deal with the following first order conditions :

$$\begin{cases} (C_1) & b\cdot f'(k\cdot(1-t(d)))\cdot(1-t(d)) - w_s(0) = 0 \\ (C_2) & b\cdot f'(k\cdot(1-t(d)))\cdot k\cdot(-t'(d)) - (w_s'(d)\cdot\lambda + w_u'(d)\cdot(1-\lambda)) - c_t'(d) + \gamma = 0 \\ (C_3) & \gamma\cdot d = 0 \quad \text{and} \quad \gamma \geq 0 \end{cases} \tag{36}$$

Moreover, we know that $d < \bar{d}$, $\lim_{x\to 0} f'(e) = +\infty$, $\lim_{x\to+\infty} f'(e) = 0$ and $f'(e) > 0$. The condition (C_1) of equation 36 is therefore equivalent to :

$$\forall d \in \left[0, \bar{d}\right[, \qquad k = \frac{1}{1-t(d)}\cdot(f')^{-1}\left(\frac{w_s(0)}{b\cdot(1-t(d))}\right) \tag{37}$$

As a consequence, (C_2) of equation 36 becomes :

$$\underbrace{\frac{w_s(0)}{(1-t(d))^2}\cdot(f')^{-1}\left(\frac{w_s(0)}{b\cdot(1-t(d))}\right)\cdot(-t'(d)) - \frac{\partial\rho(d,\lambda)}{\partial d}}_{=g(d,\lambda)} + \gamma = 0 \tag{38}$$

with $\frac{\partial\rho(d,\lambda)}{\partial d} = (w_s'(d)\cdot\lambda + w_u'(d)\cdot(1-\lambda)) + c_t'(d)$. It remains to use condition $(C3)$ in order to identify the two kinds of solution. In fact if $\gamma > 0$, one verifies that $d = 0$ and one has to make sure that $\gamma = -g(0,\lambda) > 0$. Reciprocally if $d = 0$ then $g(0,\lambda) \leq 0$. Hence $d^I(i) = 0$ if and only if :

$$\underbrace{w_s(0)\cdot(f')^{-1}\left(\frac{w_s(0)}{b}\right)\cdot(-t'(0))}_{-\Delta MC} - \underbrace{(w_s'(0)\cdot\lambda + w_u'(0)\cdot(1-\lambda))}_{-\Delta LC(i)} \leq 0 \tag{39}$$

Step 3 : *The optimal strategies.*

Case 1 : Condition (39), or equivalently $\Delta MC \geq \Delta LC(i)$, is met

In this situation, it is immediate that :

$$k^I = (f')^{-1}\left(\frac{w_s(0)}{b}\right) \qquad \text{and} \qquad d^I = 0 \tag{40}$$

Case 2 : Condition (39) is not met (i.e. $\Delta MC < \Delta LC(i)$)

In this case, it remains to make sure, that there exists a unique $d^I > 0$ which solves $g(d^I,\lambda) = 0$. So let us first make the following observations :

- Because $\lim_{d\to 0} c_t'(d) = 0$, we can assert that :

$$\lim_{d\to 0} g(d,\lambda) = w_s(0)\cdot(f')^{-1}\left(\frac{w_s(0)}{b}\right)\cdot(-t'(0)) - (w_s'(0)\cdot\lambda + w_u'(0)\cdot(1-\lambda)) \tag{41}$$

  Moreover because condition (39) is not met then we can conclude that $\lim_{d\to 0} g(d,\lambda) > 0$

- We know by proposition 1 that $\left.\frac{\partial\rho(d,\lambda)}{\partial d}\right|_{d=\bar{d}} \leq w_s'(\bar{d}) + c_t'(\bar{d})$ where $w_s'(\bar{d}) + c_t'(\bar{d})$ is finite. Moreover, we have assume that $\lim_{x\to 0} e\cdot(f'(e))^2 = +\infty$, this implies that $\lim_{y\to+\infty}(f')^{-1}(y)\cdot y^2 = +\infty$ by setting $e = (f')^{-1}(y)$, hence :

$$\lim_{d\to\bar{d}}\left(\frac{w_s(0)}{1-t(d)}\right)^2\cdot(f')^{-1}\left(\frac{w_s(0)}{b\cdot(1-t(d))}\right) = +\infty \tag{42}$$

But from $w_s(0) > 0$ and $\left(-t'(\bar{d})\right) < 0$, it follows that $\lim_{d \to \bar{d}} g(d, \lambda) = -\infty$

It therefore remains to show that $\partial_d g(d, \lambda, 0) < 0$. If this happens there exists a unique couple $\left(d^I(i), k^I(i)\right)$ which satisfies the first order conditions when condition (39) is not met. By computation, we observe that :

$$\frac{\partial g(d,\lambda)}{\partial d} = \partial_d \left(\frac{w_s(0)}{(1 - t(d))} \cdot k \cdot \left(-t'(d)\right) \right) - \frac{\partial^2 \rho(d,\lambda)}{(\partial d)^2} \tag{43}$$

By proposition 1 we know that $\frac{\partial^2 \rho(d,\lambda)}{(\partial d)^2} > 0$. Moreover

$$\begin{aligned} & \partial_d \left(\frac{w_s(0)}{(1 - t(d))} \cdot k \cdot \left(-t'(d)\right) \right) \qquad (44) \\ = \quad & \underbrace{-k \cdot \frac{w_s(0)}{(1 - t(d))^2} \cdot \left(t'(d)\right)^2}_{\leq 0} \left(1 + \underbrace{\frac{1 - t(d)}{k \cdot t'(d)} \cdot \frac{dk}{dd}}_{=A} + \underbrace{\frac{(1 - t(d)) \cdot (t"(d))}{(t'(d))^2}}_{>0} \right) \end{aligned}$$

Let us now apply the implicit function theorem to $(C1)$ of equation 36 in order to compute $\frac{dk}{dd}$. We obtain :

$$\begin{aligned} \frac{dk}{dd} &= -\frac{b \cdot (f"(k \cdot (1 - t(d))) \cdot (1 - t(d)) \cdot (-k) \cdot t'(d) - f'(k \cdot (1 - t(d))) \cdot t'(d))}{b \cdot f"(k \cdot (1 - t(d))) \cdot (1 - t(d))^2} \qquad (45) \\ &= t'(d) \cdot \frac{f"(e) \cdot e + f'(e)}{f"(e) \cdot (1 - t(d))^2} \quad \text{with} \quad e = k \cdot (1 - t(d)) \end{aligned}$$

It follows that :

$$\begin{aligned} A &= 1 + \frac{1 - t(d)}{k \cdot t'(d)} \cdot \frac{dk}{dd} = 1 + \frac{f"(e) \cdot e + f'(e)}{f"(e) \cdot e} \qquad (46) \\ &= 2 + \frac{1}{e_e(f')} \geq 0 \quad \text{because} \quad e_e\left(f'\right) \leq -\frac{1}{2} \end{aligned}$$

hence $\frac{\partial g(d,\lambda)}{\partial d} < 0$. We can therefore state the the optimal strategy solves

$$\begin{cases} k^I(i) = \dfrac{1}{1 - t(d^I(i))} \cdot (f')^{-1} \left(\dfrac{w_s(0)}{b \cdot (1 - t(d^I(i)))} \right) \\ \\ \dfrac{w_s(0)}{(1 - t(d^I(i)))^2} \cdot (f')^{-1} \left(\dfrac{w_s(0)}{b \cdot (1 - t(d^I(i)))} \right) \cdot \left(-t'(d^I(i))\right) - \dfrac{\partial \rho\left(d^I(i), \lambda(i)\right)}{\partial d} = 0 \end{cases} \tag{47}$$

and that a unique solution $(k^I(i), d^I(i))$ exists. ■

D Proof of proposition 4

It an obvious consequence of proposition 3 ■

E Proof of proposition 5

(a) If condition (39) of the proof of proposition 3 is met then $d^I(i) = 0$, hence $d^I(i) \leq d^I(i)$. So let us concentrate on the case in which this condition is not met. We know, by proposition 1, that $d^I(i)$ solves

$$\frac{\partial \rho(d^I(i), \lambda(i))}{\partial d} := w_s'\left(d^I(i)\right) \cdot \lambda(i) + w_u'\left(d^I(i)\right) \cdot (1 - \lambda(i)) + c_t'\left(d^I(i)\right) = 0 \tag{48}$$

while, by proposition 3, $d^I(i)$ verifies :

$$\underbrace{\frac{w_s(0)}{\left(1-t\left(d^I(i)\right)\right)^2}\cdot\left(f'\right)^{-1}\left(\frac{w_s(0)}{b\cdot\left(1-t\left(d^I(i)\right)\right)}\right)\cdot\left(-t'(d^I(i))\right)}_{<0}=\frac{\partial\rho(d^I(i),\lambda(i))}{\partial d} \tag{49}$$

One can therefore assert that :

$$\frac{\partial\rho(d^{LT}(i),\lambda(i))}{\partial d}<\frac{\partial\rho(d^{ST}(i),\lambda(i))}{\partial d} \tag{50}$$

But we know that $\partial_d^2\rho(d,\lambda)>0$ (see the proof of proposition 1), hence $d^{LT}(i)\leq d^{ST}(i)$

(b) If condition (39) of the proof of proposition 3 is met the result is again obvious because $d^I(i)=0$. If this is not the case, we know, by condition (38), that d^{LT} solves $g(d^I,\lambda)=0$. By the implicit function theorem, it is immediate that

$$\frac{d\left(d^I\right)}{d\lambda}=-\frac{\partial_\lambda g(d^I,\lambda,0)}{\partial_d g(d^I,\lambda,0)}=\frac{\left(w_s'(d)-w_u'(d)\right)}{\partial_d g(d^I,\lambda,0)}$$

Since $\partial_d g(d^I,\lambda)<0$ (see the proof of proposition 3) and $\left(w_s'(d)-w_u'(d)\right)>0$, we deduce that $\frac{d\left(d^I\right)}{d\lambda}<0$, or correlatively that $\left(d^I(i)\right)'>0$ ■

F Proof of proposition 6

By the envelop theorem, we have

$$\frac{d\max_{(k,d)}R(k,d)-\rho(d,\lambda)}{d\lambda}=-\left.\frac{\partial\rho(d,\lambda)}{\partial\lambda}\right|_{d=d^I}=-\left(w_s\left(d^I\right)-w_u\left(d^I\right)\right)<0 \tag{51}$$

because skilled workers earn more then unskilled workers. Moreover we know that $\lambda'(i)<0$. Hence

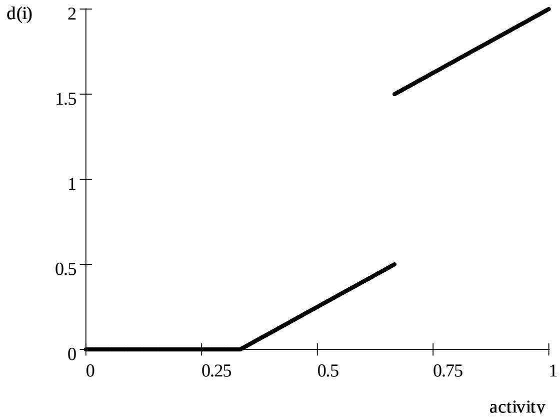
$$\left(\pi^I(i)\right)'=-\left(w_s\left(d^I(i)\right)-w_u\left(d^I(i)\right)\right)\cdot\lambda'(i)>0 \tag{52}$$

■

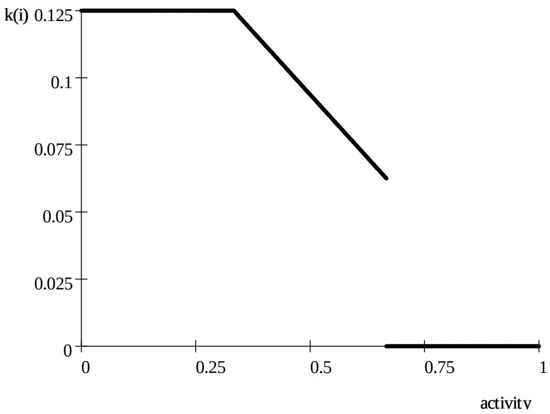
G Proof of proposition 7 and 8

The proof of proposition 7 is quite obvious if one has in mind that $\frac{d\pi^I(i)}{di}+\frac{d\rho^W(i)}{di}\leq 0$. Proposition 8 summarizes all the preceding results ■

Figure 1



optimal distance



Optimal investment

figure 2

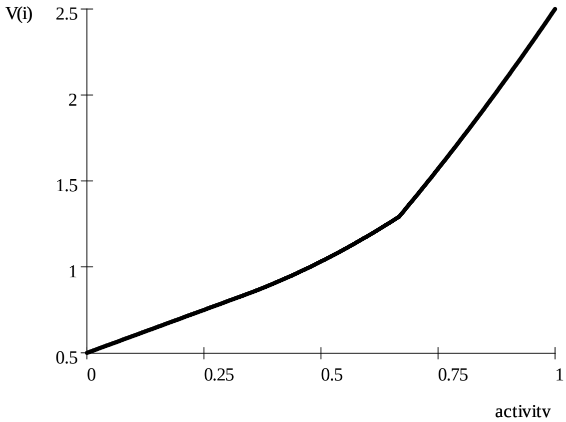
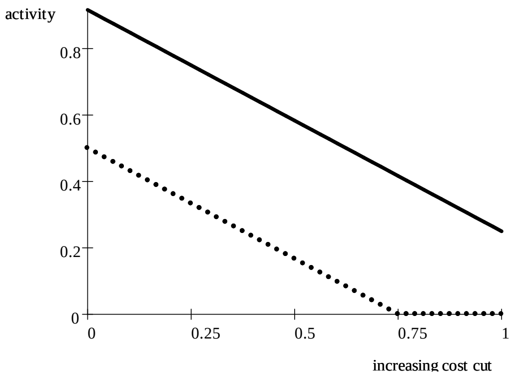
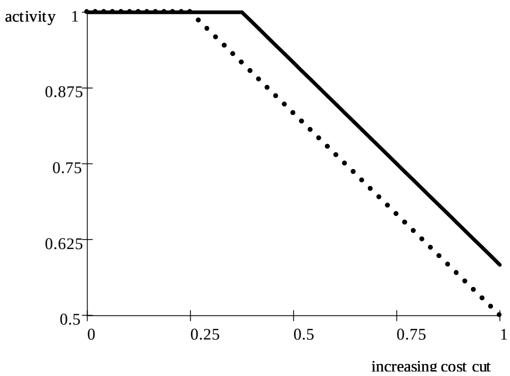


figure 3

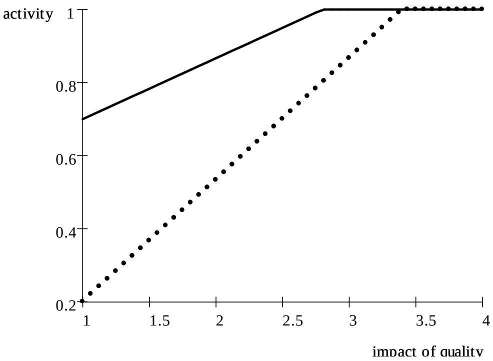


For $\beta = 1.5$ (— $i_{C/W}$ and $\cdots$ $i_{L/F}$)

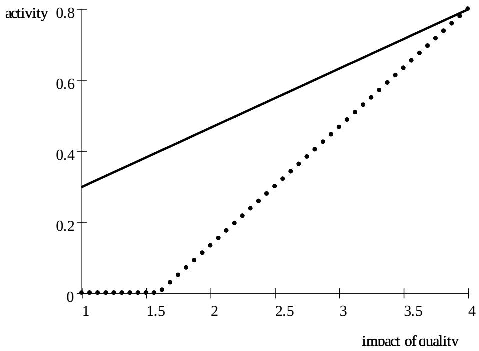


For $\beta = 3.5$ (— $i_{C/W}$ and $\cdots$ $i_{L/F}$)

figure 4



For $\alpha = 0.2$ (— $i_{C/W}$ and $\cdots$ $i_{L/F}$)



For $\alpha = 0.8$ (— $i_{C/W}$ and $\cdots$ $i_{L/F}$)