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ABSTRACT
The Impact of Labor Markets on Emergence and Persistence of Regional Asymmetries

This paper investigates the impact of labor markets and economies of agglomeration on firms location. We show that the existence of a lower bound on wage (e.g. a minimum wage or a reservation wage) introduces asymmetric location of firms. Moreover, changes in that lower bound or in global product demand may induce irreversible changes in location equilibria. Asymmetries in firms location may thus emerge and persist.

JEL Classification: J23, R30

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1 Introduction

Recently, economists have been exploring the nature of firm agglomeration into industrial clusters. When firms are located together, they benefit from costs reductions through the effects of economies of agglomeration (see e.g. Henderson (1988), Krugman (1991a), Ottaviano and Puga (1998), Feldman and Audretsch (1999) or Fujita, Krugman and Venables (1999)). For instance, Porter (1990, p. 434) reports that "[a] striking feature of successful Italian industries is geographic concentration, in which many if not hundreds of firms in one industry are located in a single town": ceramic tiles in Sassuolo, lighting in Castel Goffredo, food processing machinery in Bologna, etc.

As shown in the literature, economies of agglomeration are offset by transportation costs since these costs induce firms to operate in separate markets. However, the size of transportation costs has been diminishing for years and more industry agglomeration is expected as world globalization goes on. Still, in the absence of inter-regional mobility of workers such as in the European Union (Decressin and Fatás (1995)), competitive labor markets can also provide a dispersion force that restrains agglomeration. Since the demand for labor increases in the region in which firms agglomerate, the competitive wage can increase in that region, which would reduce the advantage of agglomeration. Picard and Toulemonde (2000) shows that firms locate symmetrically across regions when labor supply is perfectly inelastic.

However, the existence of lower bound on wage in the labor markets tempers the dispersion force. Indeed, changes in labor demand do not entail changes in wages when wages stick to a reservation wage or when they are bound to minimum wages. On the one hand, reservation wages are likely to have a strong impact in industries that employ skilled workers, e.g. design industry, computer industry, space industry, ... On the other hand, since minimum wages have been widely introduced in European countries (European Commission (1997)), they surely become an issue in many low wage industries. The focus of this paper is precisely to study the interaction between reservations wages, minimum wages and economies of agglomeration.

We build on Ottaviano and Thisse (1999) and on Belleflamme, Picard and Thisse (2000). In contrast to Krugman (1991b), we present a partial equilibrium model of an industry in which firms sell differentiated products to customers located in two regions (cities). We focus on the European socio-economic context in which workers may be considered as immobile but in which firms choose their regional location. We model reservation wages and minimum wages as lower bounds below which wages cannot fall. Since both concepts accept equivalent modelling, we concentrate our attention on the impact of minimum wages on agglomeration. The extension to reservation wages is straightforward. Finally, we take the economies of agglomeration as given, that is, we assume that there exists a function that links the number of firms in one region to the productivity of workers in that region.

Many stylized facts about industrial clustering fit this model. Again, Italian industrial clusters provide a good example. Clusters occur in labor intensive industries. Numerous small firms produce highly diversified goods. Workers are closely attached to their industry and to their particular region. Within an industry, networks of (often family or community related) producers in the concentrated regions allow for rapid diffusion of technologies and innovations which yields strong economies of agglomeration (Porter 1990).

The presence of minimum wages introduces asymmetric location equilibria that do not exist with competitive labor markets. We show that, even if the minimum wage lies below the wage that would prevail in competitive labor markets, agglomeration in one region (city) becomes a new equilibrium. Moreover, we show that changes in minimum wages or in global product demand may induce irreversible changes in location equilibria. Under the presence of minimum wages, asymmetries in firms location may thus emerge and persist. The impact of reservation wages on agglomeration can be derived from these results. In particular, firms may persistently agglomerate in one region in industries where reservation wages have temporarily risen or in which demand has temporarily decreased.

The paper is organized as follows. Section 2 presents the model and Section 3 studies the location equilibria when the minimum wage binds in zero, one or two regions. Section 4 provides a discussion that gathers together the previous results when a common minimum wage is set by a central entity, and when minimum wages are independently set in each region. A conclusion follows.

2 The Model

In this paper we build on the Belleflamme, Picard and Thisse (2000) model of imperfect competition with differentiated products. We consider an industry where each firm produces a differentiated variety i of commodity and where varieties are picked in the interval $[0, 1]$. The assumption of continuous varieties improves the model tractability. Indeed, the location of firms becomes a continuous process rather than a discrete process as in models with a finite number of varieties or firms.

2.1 Consumers

The representative consumer's utility function is

$$U(q_0; q(i), i \in [0,1]) = \alpha \int_0^1 q(i)di - \frac{\beta - \delta}{2} \int_0^1 q(i)^2 di - \frac{\delta}{2} \int_0^1 \int_0^1 q(i)q(j)didj + q_0 \quad (1)$$

where $q(i)$ is the quantity of variety $i \in [0, 1]$ and q_0 the quantity of the numéraire. The parameters are such that $\alpha > 0$ and $\beta > \delta > 0$. In expression (1), α expresses the intensity of preferences for the differentiated product with respect to the numéraire. The hypothesis $\beta > \delta$ means that the representative consumer is biased toward a dispersed consumption of varieties. Thus, it reflects a love for variety.

The consumer is endowed with $\overline{q}_0 > 0$ units of the numéraire. Her budget constraint can then be written as follows:

$$\int_0^1 p(i)q(i)di + q_0 = \overline{q}_0$$

where $p(i)$ is the price of variety i and q_0 her consumption of the numéraire. The initial endowment $\overline{q}_0$ is supposed to be large enough for the optimal consumption of the numéraire to be strictly positive at the market outcome.

Solving the budget constraint for the numéraire consumption, plugging the corresponding expression into (1) and solving the first order conditions with respect to $q(i)$ yields

$$\alpha - (\beta - \delta)q(i) - \delta \int_0^1 q(j)dj = p(i), \quad i \in [0,1]$$

The demand function for variety $i \in [0,1]$ can be written as

$$q(i) = a - bp(i) + d \int_0^1 [p(j) - p(i)]dj \tag{2}$$

where $a \equiv \alpha/\beta$, $b \equiv 1/\beta$ and $d \equiv \delta/\beta(\beta - \delta)$.

Parameter a is a measure of the size of the product market. Parameter b gives the link between individual and industry demand. When b increases, consumers are more sensitive to the output price. The degree of product differentiation between varieties is reflected by parameter d. When varieties are perfect substitute, $d \to \infty$, whereas, when they are independent, $d = 0$, and firm i has monopoly power on variety i.

2.2 Firms

There are two regions A and B with N_K firms in region $K \in \{A, B\}$. Since varieties are picked in the interval $[0,1]$, we have $N_K \in [0,1]$ and $N_A + N_B = 1$. In a first step, we study the process of competition between firms for a given spatial distribution (N_A, N_B) of firms. As in Ottaviano and Thisse (1999), each firm has a zero mass and has no direct impact on the market. Hence, when choosing prices, a firm in A neglects the impact of its decision over the regional price indices. In addition, because firms sell differentiated varieties, each one has some monopoly power in that it faces a demand function with finite elasticity. However, in the determination of its own price, each firm accounts for the price index of each region. As a consequence, our market solution is given by a Nash equilibrium with a continuum of players in which prices are interdependent: each firm neglects its impact on the market but is aware that the market as a whole has a non-negligible impact on its behavior.

The absence of transportation costs and the assumption of identical consumers implies that firms do not have any incentive to discriminate consumers by setting different prices across regions (see Belleflamme, Picard and Thisse, 2000, for the role of transportation costs). Each firm i sells the variety i at the same price in both regions. We adopt the following notation:

$$P_K \equiv \int_{i \in K} p_K(i)\, di$$

By (2), demands for firm $i \in K$ are then given by:

$$2q_K(i) = a - (b+d)p_K(i) + d(P_K + P_L) \text{ where } K \neq L,\ L \in \{A, B\}$$

Firm i maximizes profits defined by:

$$\Pi_K(i) = 2q_K(i)[p_K(i) - c_K] \tag{3}$$

where c_K is the marginal cost in region K.

We first differentiate (3) with respect to prices $p_K(i)$ to obtain the first order conditions. Integrating the corresponding expressions across firms i located in K, we obtain the following equation:

$$[2(b+d) - dN_K]P_K - dN_K P_L = N_K[a + (b+d)c_K] \text{ where } K \neq L \tag{4}$$

Since profit functions are concave in own price and varieties are symmetric, solving the system of equations (4) for $K \in \{A, B\}$ yields the equilibrium prices and quantities:

$$p_K = \frac{c_K}{2} + \frac{2a + d[N_A c_A + N_B c_B]}{2(2b+d)} \tag{5}$$

$$q_K = (b+d)(p_K - c_K) \tag{6}$$

The prices and quantities of varieties produced in region K may differ from those produced in region $L \neq K$ because the cost conditions may be different.

The equilibrium profits of any firm located in region K are thus

$$\Pi_K = 2(p_K - c_K)q_K = \begin{cases} 2(b+d)(p_K - c_K)^2 \text{ if } p_K > c_K \\ \quad 0 \quad \text{otherwise.} \end{cases}$$

If the difference in profitability between region A and region B is positive, firms leave region B to go in region A, and vice versa. Therefore, the difference in profitability between the two regions is the key indicator that determines the location of firms. Using (5), the difference in profitability may be written as

$$\begin{aligned}\Delta\Pi &\equiv \Pi_A - \Pi_B \\ &= 2(b+d)\left[(p_A - c_A)^2 - (p_B - c_B)^2\right] \\ &= (b+d)\left[c_B - c_A\right]\left[(p_A - c_A) + (p_B - c_B)\right]. \qquad (7)\end{aligned}$$

Our objective is to highlight regional asymmetries in the context of structurally identical regions. We assume that whatever the number of firms in one region, production would generate some surplus in that region, that is, the highest valuation of any variety (a/b) is always greater than the marginal costs:

$$\frac{a}{b} > c_K \ \forall K \text{ and } \forall N_K \in [0,1] \qquad \text{(A1)}$$

This assumption strengthens the structural symmetry but still allows for asymmetric outcomes. Its main advantage is to simplify the presentation by avoiding binding constraints on quantities, i.e. $q_K = 0$. Hence, in the rest of the paper, $q_K > 0$. Therefore $p_K > c_K$ and the last bracket in expression (7) is strictly positive.

From expression (7), it is clear that the difference in profitability between regions depends on the marginal costs: c_A and c_B. Since marginal costs depend on nature of agglomeration and on labor markets, the location equilibrium depends on the shape of the economies of agglomeration and on the properties of the labor market.

2.3 Labor Costs and Economies of Agglomeration

Marginal costs depend on labor costs and on the economies of agglomeration. We do not endogenize the economies of agglomeration. Rather, we assume that there exists a function that relates the number of firms in one region to the productivity of workers in that region. Moreover, we assume that this function is linear. These assumptions convey the main ideas behind economies of agglomeration and they allow to get analytically tractable expressions that are useful to present the mechanisms that explains the emergence and persistence of asymmetries[1].

In accordance with a stylized fact of the European labor markets, we assume that the workers are immobile in the sense that they cannot move between regions (see Decressin and Fatás (1995) who show that workers are rather immobile in Europe, even within countries). Worker productivity is independent of the level of production in the firm but it varies with the intensity of agglomeration in the region. We assume that, in each region $K \in \{A, B\}$, the production of one good requires $\beta(1-\theta N_K)$ workers where $(1-\theta N_K)$ represents the productivity improvement due to agglomeration economies. The marginal costs in region K are

$$c_K = \beta w_K\ (1-\theta N_K)$$

where w_K is the market wage in region K. As in Belleflamme, Picard and Thisse (2000), the marginal costs of firms in region K linearly decrease as the number of firms in that region rises. To keep positive marginal costs, we assume that $\theta \in [0,1)$.

The labor demand in region K is then

$$L_K^D = 2N_K\beta(1-\theta N_K)q_K$$

We assume that there exists a minimum wage $\underline{w}_K$ which may differ across regions. As mentioned in the introduction, $\underline{w}_K$ is a lower bound on wage that can also be intrepreted as the reservation wage in region K. We model the labor supply as follows:

$$L_K^S = \begin{cases} \varepsilon \text{ if } w_K > \underline{w}_K \\ (0,\varepsilon) \text{ if } w_K = \underline{w}_K \\ 0 \text{ if } w_K < \underline{w}_K \end{cases}$$

[1] The alternative is to endogenize the economies of agglomeration (for instance through an input-output structure as in Venables (1996)), or to use non linear functions. However, this would make the model analytically intractable and we should resort to numerical simulations to present results that would be qualitatively similar.

where ε is positive. Therefore the labor market equilibrium is given by

$$2N_K\beta(1-\theta N_K)q_K = \begin{cases} \varepsilon \text{ if } w_K > \underline{w}_K, \\ (0,\varepsilon) \text{ if } w_K = \underline{w}_K, \\ 0 \text{ if } w_K < \underline{w}_K. \end{cases}$$

3 Location Equilibria and Minimum Wages

In this section, we analyze the location equilibria in three configurations of labor markets. As a benchmark, we first study competitive labor markets. This situation occurs when minimum wages never bind for any location of firms. We then present the case in which minimum wages always bind in both regions for any location. Finally we develop the most interesting situation where a minimum wage binds in only one region for any location. These three configurations of labor markets are clearly restrictive since several configurations can simultaneously appear. For instance, for a same set of parameters, it is possible that minimum wages bind in both regions at the symmetric location and that the minimum wage does not bind in one region if full agglomeration takes place in that region. This issue is studied in the next section.

Before proceeding to the characterization of the location equilibrium, it is convenient to take advantage of the symmetry of the problem by setting $\Delta N \equiv N_A - N_B$. Thus, $N_A = (1/2)(1+\Delta N)$, $N_B = (1/2)(1-\Delta N)$. A location equilibrium is defined as follows:

Definition 1 *A* location equilibrium *is such that no locational deviation by a single firm is profitable.*

Hence, there must be no incentives for firms to relocate. If a region offers higher profits than the other, firms will move to that location until the *profit differential* $\Delta\Pi(\Delta N)$ between the regions falls to zero or until all firms are located in that region. A *location equilibrium* arises at an interior point $N_K \in (0,1)$ when $\Delta\Pi(\Delta N) = 0$, or at corners points $N_A = 0$ when $\Delta\Pi(-1) \leq 0$, and $N_A = 1$ when $\Delta\Pi(1) \geq 0$. In the first case, we have either two identical clusters or two asymmetric clusters; in the last two cases, we have a single cluster.

Definition 2 *A location equilibrium ΔN^* is* stable *if, in the neighborhood of ΔN^*, no locational deviation by a group of firms (non zero mass) is profitable.*

Continuity of the profit functions implies that corner solutions are always stable. For interior solutions ΔN^* where $\Delta\Pi(\Delta N^*) = 0$, stability implies that $\Pi_A - \Pi_B$ decreases (resp. increases) if a group of firm moves from B to A (resp. A to B). That is, the slope of $\Delta\Pi(\Delta N)$ must be negative in the neighborhood of the equilibrium.

Several kinds of equilibria may arise in this setting. Either all firms agglomerate in one region (corner solution) or they spread across regions (interior solution) in a way that equalizes profits. In the latter case, firms can spread evenly ($\Delta N = 0$) or unevenly across regions. We now characterize the stable location equilibria according to various settings of labor markets.

3.1 Competitive Labor Markets

When labor markets are competitive in both regions, the equilibrium level of employment is given by

$$2N_K\beta(1-\theta N_K)q_K = \varepsilon \ \forall K \in \{A, B\} \tag{8}$$

It is easy to derive the following proposition:

Proposition 3 *Under competitive labor markets, the symmetric location ($\Delta N^* = 0$) is the unique stable location equilibrium.*

Proof. (i) Interior equilibria require that $\Delta\Pi(\Delta N) = 0$. By (7), this implies that $c_A = c_B$. Thus, by (5) and (6), $p_A = p_B$ and $q_A = q_B$. By (8), $2N_A\beta(1-\theta N_A)q_A = 2N_B\beta(1-\theta N_B)q_B$. Thus, $N_A(1-\theta N_A) = N_B(1-\theta N_B)$. Hence, $N_A = N_B$ and $\Delta N^* = 0$.

(ii) A corner equilibrium at $\Delta N = 1$ is impossible. Indeed, suppose that $\Delta N = 1$, then $N_B = 0$ and $L_B = 0$. Thus, $w_B = 0$ and $c_B = \beta w_B = 0$.

Since $N_A = 1$, $L_A = \varepsilon$ and $w_A > 0$. Therefore, $c_A = \beta w_A(1-\theta) > 0$. Hence, $c_B - c_A < 0$ and by (7), $\Delta\Pi(1) < 0$, which is a contradiction. By symmetry, corner equilibrium at $\Delta N = -1$ is also impossible.

(iii) Stability at $\Delta N^* = 0$ is granted. The function $\Delta\Pi(\Delta N)$ is indeed continuous; by (i), it has a unique zero at $\Delta N = 0$; by (ii), it is positive at $\Delta N = 1$ and negative at $\Delta N = -1$. The slope of this function must therefore be negative at $\Delta N = 0$. ■

The intuition is as follows. Firms never agglomerate in a single cluster because full agglomeration in one region would push the demand for labor and the wage in the deserted region to zero. This would definitely entice firms to locate in the deserted region. The fact that firms locate in identical clusters results from the assumption of identical labor supplies. Symmetry implies that economies of agglomeration and labor demands are identical in each cluster. If labor supplies were different, the location equilibrium would be biased toward the region with the largest labor supply (but probably not in proportion of the structural asymmetries in the labor markets, see Ottaviano and Puga (1998)). The uniqueness of the equilibrium results from the linear shape of product demand and from the perfectly inelastic nature of the labor supplies. As shown in Picard and Toulemonde (2000), additional equilibria may occur under more general labor supplies.

Under this symmetric equilibrium ($N_K = 1/2$), wages and marginal costs are identical in both regions: $w_K = w^*$ and $c_K = \beta w^*(1-\theta/2)$. So are the quantities

$$q_K = \frac{b+d}{2b+d}\left(a - b\beta w^*\left(1-\frac{\theta}{2}\right)\right)$$

Plugging this expression in (8) for $N_K = 1/2$ yields the competitive wage

$$w^* = \frac{1}{b\beta^2(1-\frac{\theta}{2})}\left(a\beta - \frac{\varepsilon}{1-\frac{\theta}{2}}\frac{2b+d}{b+d}\right) \tag{9}$$

Under (A1), the competitive equilibrium is always feasible, that is

$$\frac{a}{b} > c_K = \beta w^*(1-\theta/2). \tag{10}$$

3.2 Minimum Wages Binding in Both Regions

When minimum wages bind in both regions, firms have the following marginal costs:

$$c_K = \beta \underline{w}_K \left(1 - \theta N_K\right)$$

Since wages are rigid, agglomeration in one region does not alter labor costs but generates economies of agglomeration. Full agglomeration is therefore expected, as confirmed by the following proposition:

Proposition 4 *When minimum wages bind in both regions, firms agglomerate in a single cluster. They agglomerate only in region A if* $\underline{w}_A/\underline{w}_B < (1-\theta)$ *or only in region B if* $\underline{w}_A/\underline{w}_B > 1/(1-\theta)$*. They agglomerate in any region A or B if* $(1-\theta) < \underline{w}_A/\underline{w}_B < 1/(1-\theta)$*.*

Proof. (i) Interior equilibria are always unstable. Note first that

$$\begin{aligned} c_B - c_A &= \beta[\underline{w}_B(1-\theta N_B) - \underline{w}_A(1-\theta N_A)] \\ &= \beta\left[\left(1-\frac{\theta}{2}\right)(\underline{w}_B - \underline{w}_A) + \frac{\theta}{2}(\underline{w}_A + \underline{w}_B)\Delta N\right] \end{aligned}$$

which is increasing in ΔN. By (7), the profit differential $\Delta\Pi(\Delta N)$ has a unique zero at $\Delta\widetilde{N} = -\left(2-\theta\right)\left(\underline{w}_B - \underline{w}_A\right)/(\theta(\underline{w}_A + \underline{w}_B))$ and is increasing at this point. Therefore any interior location equilibrium $\Delta\widetilde{N} \in [-1,1]$ is unstable.

(ii) The corner equilibrium $\Delta N = 1$ requires that $\Delta\Pi(1) > 0$, i.e., by (7),

$$c_B - c_A = \beta\left[\left(1-\frac{\theta}{2}\right)(\underline{w}_B - \underline{w}_A) + \frac{\theta}{2}(\underline{w}_A + \underline{w}_B)\right] > 0$$

which is equivalent to $\underline{w}_B > (1-\theta)\underline{w}_A$. A similar argument indicates that $\Delta N = -1$ is a corner equilibrium if $\underline{w}_A > (1-\theta)\underline{w}_B$. ■

3.3 Minimum Wage Binding in One Region

In this section we study the situation where the minimum wage binds in only one region, say region B. Therefore, the labor market is characterized by

$$L_A^S = \varepsilon \text{ and } w_B = \underline{w}_B$$

When labor market clears in region A, we have $2N_A\beta q_A(1-\theta N_A)=\varepsilon$ where by (5) and (6)

$$q_A=\frac{b+d}{2}\left[-c_A+\frac{2a+d\left(N_Ac_A+N_Bc_B\right)}{2b+d}\right]$$

In region B, $c_B=\beta\underline{w}_B(1-\theta N_B)$. Using these three expressions, one obtains

$$c_B-c_A=\frac{1}{\beta\left(2b+dN_B\right)N_A}\left[\frac{\varepsilon}{\left(1-\theta N_A\right)}\frac{2b+d}{b+d}-2a\beta N_A+2b\beta^2\underline{w}_B(1-\theta N_B)N_A\right]$$

which, using (9), can also be written in function of ΔN as

$$c_B-c_A=\frac{Z\left(\Delta N\right)}{4N_A\left(2b+dN_B\right)\left(1-\theta N_A\right)}$$

where

$$\begin{aligned} Z\left(\Delta N\right) &= -\beta b\underline{w}_B\theta^2\left(\Delta N\right)^3+\theta\left(2a-b\beta\underline{w}_B\theta\right)\left(\Delta N\right)^2 \\ &\quad -\left(4a\left(1-\theta\right)-b\beta\underline{w}_B\left(2-\theta\right)^2\right)\Delta N+b\beta\left(\underline{w}_B-w^*\right)\left(2-\theta\right)^2 \end{aligned} \quad (11)$$

From (7), the profit differential has the same zeros and the same sign as $Z\left(\Delta N\right)$. The study of location equilibria is thus equivalent to the analysis of $Z\left(\Delta N\right)$.

Let us define $\widehat{w}$ such that $Z\left(\Delta N\right)=0$ at $\Delta N=1$ when $\underline{w}_B=\widehat{w}$. One can compute

$$\widehat{w}\equiv\frac{1}{2b\beta^2}\left(2a\beta-\frac{\varepsilon}{\left(1-\theta\right)}\frac{2b+d}{b+d}\right).$$

It is easy to check that $Z\left(\Delta N\right)$ increases with $\underline{w}_B$, and thus, the profit differential increases with $\underline{w}_B$. Let also denote $\widetilde{w}$ the smallest minimum wage $\underline{w}_B$ such that the $\Delta N-$cubic expression of $Z(\Delta N)$ takes non negative values for all $\Delta N\in[-1,1]$. If $\underline{w}_B>\widetilde{w}$, then $Z\left(\Delta N\right)$ has no root over the interval $[-1,1]$. Note that $\widehat{w}\leq\widetilde{w}$. Indeed, suppose that $\widehat{w}>\widetilde{w}$, then $Z\left(\Delta N\right)$ has no root when $\underline{w}_B=\widehat{w}$ which contradicts the definition of $\widehat{w}$ (i.e. $Z\left(\Delta N\right)=0$ at $N_A=1$ when $\underline{w}_B=\widehat{w}$).

We can then derive the following proposition.

Proposition 5 *When the minimum wage binds only in region B, one or two location equilibria may be stable.*
(i) If $\underline{w}_B < \widehat{w}$, then there exists a unique stable equilibrium with partial (or no) agglomeration; there is no agglomeration if $\underline{w}_B = w^*$.
(ii) If $\widehat{w} \leq \underline{w}_B \leq \widetilde{w}$ then there exist two stable equilibria: one with full agglomeration in region A and another with partial (or no) agglomeration; there is no agglomeration if $\underline{w}_B = w^*$.
(iii) Otherwise, there exists a unique stable equilibrium with full agglomeration in region A.

Proof. In this proof we use the following definition: a function $f(x)$ is U-shaped on the inteval $[\underline{x}, \overline{x}]$ if there exists an $\widehat{x} \in [\underline{x}, \overline{x}]$ such that $f'(x) \leq 0$ $\forall\ x \in [\underline{x}, \widehat{x}]$ and $f'(x) \geq 0$ $\forall\ x \in [\widehat{x}, \overline{x}]$. Thus, the function $f(x)$ is, (1) decreasing on the whole interval, or (2) increasing on the whole interval, or (3) decreasing on the first part of the interval and then increasing.

First, we establish the following lemma:

Lemma *$Z(\Delta N)$ is U-shaped on $[-1, 1]$ with $Z(-1) > 0$.*

The fact that $Z(-1) > 0$ is easily checked. Letting $\Delta N = -1$, $Z(\Delta N)$ becomes $(2-\theta)(b\beta w^*\theta + 2(a - b\beta w^*))$ which is positive since $a > b\beta w^*$ (see the assumption A1).

The fact that $Z(\Delta N)$ is U-shaped on $[-1, 1]$ is obtained by observing the first derivative of $Z(\Delta N)$,

$$Z'(\Delta N) = -3b\beta\underline{w}_B\theta^2(\Delta N)^2 - 2\theta(-2a + b\underline{w}_B\beta\theta)\Delta N + (\theta - 1)4a + b\beta\underline{w}_B(\theta - 2)^2.$$

It has two roots:

$$\Delta N_1 = \frac{2a - b\underline{w}_B\beta\theta - 2\sqrt{\rho}}{3b\beta\underline{w}_B\theta},$$
$$\Delta N_2 = \frac{2a - b\underline{w}_B\beta\theta + 2\sqrt{\rho}}{3b\beta\underline{w}_B\theta},$$

where

$$\rho = \left(a + \underline{w}_B b\beta\left(\frac{-3 + 2\theta}{2}\right)\right)^2 + \frac{3}{4}\underline{w}_B^2 b^2\beta^2 > 0$$

Since the coefficient of the cubic term of $Z(\Delta N)$ is negative and since $\Delta N_1 < \Delta N_2$, $Z(\Delta N_1)$ is a local minimum and $Z(\Delta N_2)$ is a local maximum.

The local maximum ΔN_2 does however not belong to the interval $[-1, 1]$. To see this, note first that ΔN_2 increases with a. Hence, ΔN_2 takes its lowest value when a is the lowest. In region B, assumption A1 can be written as $a \geq b\beta\underline{w}_B$. Thus, the lowest value of ΔN_2 is for $a = b\beta\underline{w}_B$. In that case, $\Delta N_2 = \left(2 - \theta + 2\sqrt{(1 - \theta + \theta^2)}\right)/3\theta$, which decreases in θ. When $\theta = 1$, $\Delta N_2 = 1$. Therefore, ΔN_2 is always greater than or equal to 1.

Hence, since the maximum lies outside $[-1, 1]$, $Z(\Delta N)$ must be U-shaped on $[-1, 1]$, which proves the lemma.

Now we can prove the Proposition.

(i) Suppose $\underline{w}_B < \widehat{w}$. Then, $Z(1) < 0$. Since $Z(-1) > 0$ and since $Z(\Delta N)$ is U-shaped and continuous, $Z(\Delta N)$ has a unique root ΔN^* in $[-1, 1]$ such that $Z'(\Delta N^*) < 0$. Hence, ΔN^* is a stable equilibrium. When $\underline{w}_B = w^*$, $\Delta N = 0$ is a root of $\Delta\Pi(\Delta N)$.

(ii) Suppose $\widehat{w} \leq \underline{w}_B \leq \widetilde{w}$. Then, since $\widehat{w} \leq \underline{w}_B$, $Z(1) > 0$ and $\Delta N^* = 1$ is a stable equilibrium. Also, by $\underline{w}_B \leq \widetilde{w}$, $Z(\Delta N)$ takes negative values in $[-1, 1]$. Since $Z(-1) > 0$, since $Z(1) > 0$ and since $Z(\Delta N)$ is U-shaped and continuous, $Z(\Delta N)$ has two roots in $[-1, 1]$. The smallest root ΔN^{**} is such that $Z'(\Delta N^{**}) < 0$. Hence, ΔN^{**} is a stable equilibrium. When $\underline{w}_B = w^*$, $\Delta N = 0$ is a root of $\Delta\Pi(\Delta N)$.

(iii) Suppose $\underline{w}_B > \widetilde{w}$. Then, $Z(\Delta N) > 0$ for all $\Delta N \in [-1, 1]$. So, $Z(1) > 0$ and $\Delta N^* = 1$ is the unique stable equilibrium. ■

4 Discussion

As announced in the previous section, several configurations of the labor markets can simultaneously occur. For instance, assume that minimum wages are binding in both regions. Then, if firms relocate in one region, the labor market could become competitive in that region while the minimum wage would remain binding in the deserted region. As another example, assume that minimum wages do not bind for a particular location of firms. Then, if firms relocate in one region, wages in that region rise whereas wages in the deserted region fall. They could fall to the minimum wage. In this section, we show how full or partial agglomeration can be the result of the introduction of a minimum wage in an economy in which the symmetric equilibrium prevailed. We also show that hysteresis effects occur. In the next sub-section we focus on the genuine symmetric case in which minimum wages are identical. We then discuss the case when minimum wages are set to different values across regions.

4.1 Identical Minimum Wages

In this section, we assume that minimum wages are identical in both regions, that is, $\underline{w}_A = \underline{w}_B = \underline{w}$. Note that, since the labor demand in region K increases with the number of firms in that region, N_K, and decreases with that in the other region, N_L, wages in region K rise with N_K and fall with N_L.

$$\frac{dw_K}{dN_K} \geq 0 \text{ and } \frac{dw_K}{dN_L} \leq 0$$

Hence, more agglomeration in a region relaxes the minimum wage constraint in that region and strengthens the constraint in the other region. Two cases may be encountered according to the configuration of the labor market at the symmetric location.

First, suppose that none of the minimum wages bind at this symmetric location ($\underline{w} \leq w^*$). Then, in Figure 1.a, the profit differential around the symmetric location is depicted by the decreasing plain curve that crosses the origin at $\Delta N = 0$. The symmetric location is thus a stable equilibrium (as proved in Section 3.1).

However, as more firms locate in region K, wages in region L fall and can hit the minimum wage constraint. In this case, the profit differential is presented by the two dotted curves in Figure 1.a (see (11) in Section 3.3). In the figure, the U-shaped curve represents the situation in which the minimum wage binds in region B but not in region A, whereas the inverse U-shaped curve represents the situation in which the minimum wage binds in region A but not in region B. The configuration of the labor market switches at $\Delta N =$

$\pm\Delta N_1$. Labor markets clear in both regions for $|\Delta N| \leq \Delta N_1$ but minimum wage binds in the deserted region for $|\Delta N| > \Delta N_1$. The resulting profit differential is presented by the bold curve which takes a positive (negative) value when firms fully agglomerate in region A (B): $\Delta\Pi \gtrless 0$ at $\Delta N = \pm 1$. As proved in Proposition 5, this occurs if $\underline{w} \geq \widehat{w}$. Hence, *fully asymmetric equilibria can be stable at the same time as the symmetric equilibrium.* The stable equilibria are represented by the grey dots in Figure 1.a.

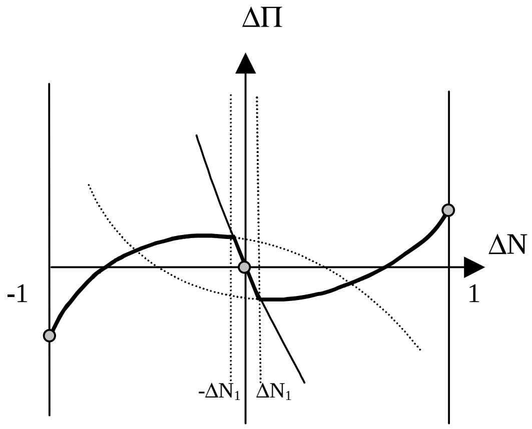

Figure 1.a

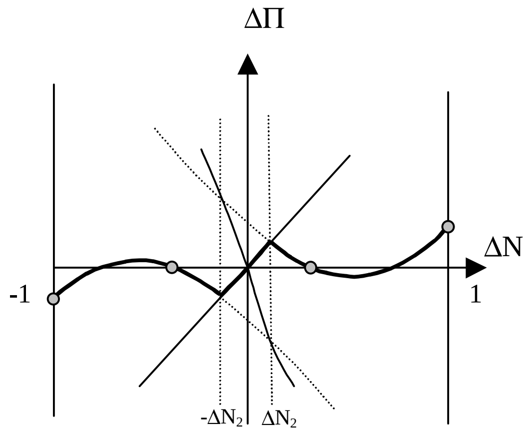

Figure 1.b

Second, suppose that the minimum wage binds in both regions at the symmetric location ($\underline{w} > w^*$). Then, in Figure 1.b, the profit differential around the symmetric location is depicted by the rising plain curve crossing the origin. The symmetric location is unstable (as proved in Section 3.2). As more firms locate in region K, the labor demand increases in that region and the minimum wage constraint is relaxed. The configuration of the labor market switches at $\Delta N = \pm\Delta N_2$. Minimum wages bind in both regions for $|\Delta N| \leq \Delta N_2$ while it binds only in the deserted region for $|\Delta N| > \Delta N_2$. In this case, the profit differential is presented by the dotted curves (defined by (11) in Section 3.3). Figure 1.b shows the most interesting situation of location equilibria. Indeed, the profit differential (bold curve) has five zeros; only those two that lie on the decreasing sections of $\Delta\Pi$ correspond to stable equilibria. Moreover, the profit differential takes a positive (negative) value when firms fully agglomerate in region A (B). Therefore, *fully asymmetric equilibria can be stable at the same time as partially asymmetric equilibria.* Partially asymmetric equilibria exist only if the smallest root of $\Delta\Pi$ belongs to $(0, 1]$ (see items (i)-(ii) of Proposition 5). When $\underline{w}$ tends to w^*, the partially asymmetric equilibria tend to the symmetric outcome.

The set of location equilibria are depicted by the bold line in Figure 2. In the case where the minimum wage binds in region B only, we have seen that the profit differential decreases with $\underline{w}$, whereas when it binds in region A only, it increases with $\underline{w}$ (see the function $Z(\Delta N)$). Hence, for low values of the minimum wage, firms locate in symmetric clusters. It is Figure 1.a in which the relevant part of the inverse U-shaped curve (low values of ΔN) is always positive and the relevant part of the U-shaped curve (high values of ΔN) is always negative. For intermediate values of the minimum wage, firms may agglomerate in single clusters or they may locate in symmetric clusters. It is Figure 1.a. When the minimum wage is larger than w^*, it binds at the symmetric location. We get Figure 1.b in which firms may agglomerate in single clusters or in partially asymmetric clusters. The partially asymmetric equilibria abruptly disappears when the minimum wage is higher than $\tilde{w}$: the inverse U-shaped curve is always below the horizontal axis whereas the U-shaped curve is always above it. Thus, for large values of minimum wages, firms agglomerate in a single cluster. It is worth to note that *the introduction of minimum wages lower (or equal to) than the competitive equilibrium may generate full agglomeration.*

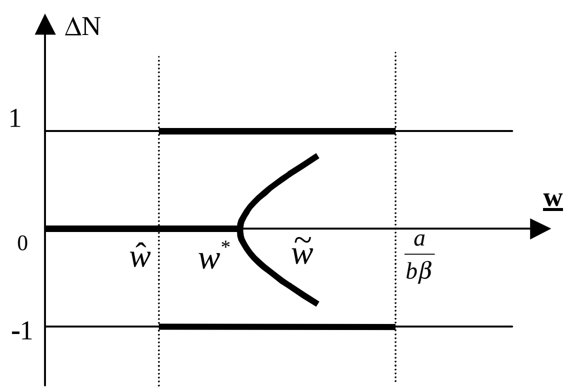

Figure 2

This analysis applies to countries or federations in which minimum wages are set by a central entity to identical levels. For instance, this is the case in Belgium, Denmark, France, Spain, or the US (see Layard, Nickell and Jackman (1991, p. 517-24)).

It is natural to assume that history contributes to the selection of the location equilibrium among the set of stable equilibria. Suppose that a minimum wage $\underline{w}$ has been set below but close to $\widetilde{w}$. Also assume that, by history, there is partial asymmetric location in region A ($0 < \Delta N_1 < 1$). If the central entity decides to increase the minimum wage above $\widetilde{w}$ then the previous location becomes unstable because the profit differential favors region A ($\Delta\Pi(\Delta N_1) > 0$). It is Figure 1.b in which the U-shaped curve has moved upwards and is now above the horizontal axis. This attracts firms in region A until full agglomeration takes place in that region. However, starting from this new equilibrium ($\Delta N_2 = 1$), any decrease in the minimum wage will not restore the previous equilibrium because it keeps the profit differential in favor of region A ($\Delta\Pi(\Delta N_2) > 0$), which induces firms to stay in that region. Full agglomeration remains the location equilibrium until the profit differential favors region B ($\Delta\Pi(\Delta N_2) < 0$), i.e., $\underline{w}$ falls below $\widehat{w}$. In section 3.3, we have shown that $\widetilde{w} > \widehat{w}$. This argument allows us to make the following proposition.

Proposition 6 *Under identical minimum wages, the following* hysteresis effect *takes place: on the one hand, once full agglomeration occurs, it persists until the minimum wage falls below $\widehat{w}$. On the other hand, once symmetric or partially asymmetric equilibria occur, they persist until the minimum wage rises above $\widetilde{w} > \widehat{w}$.*

If the central entity does not want to reduce the minimum wage below $\widehat{w}$, other policy instruments are then needed to counter the negative hysteresis effect and to restore some symmetry. For instance, it could impose taxes on firms' profits that are differentiated according to the location, it could forbid the delocalization of a (small) mass of firms, etc.

In this section we have analyzed the impact of variations in the minimum wage on firms location. Product demand also plays an important role for the firms' agglomeration. One can easily show that an increase in the global demand a raises the competitive wage w^*, and the wage $\widehat{w}$. In Figure 2, this corresponds to a shift of all curves to the right. Holding the minimum wage fixed and increasing the global demand a, one can draw the locus of location equilibria as a function of $1/a$. This would yield a figure that is similar to Figure 2 in which $\underline{w}$ is replaced by $1/a$. On the one hand, once full agglomeration has occurred, it persists until the global demand rises above a first threshold $\widehat{a}$. On the other hand, once symmetric or partially asymmetric equilibria have occurred, they persist until the global demand drops below a second threshold $\widetilde{a} < \widehat{a}$. Hence, hysteresis effects again occur and similar policy implications hold.

4.2 Asymmetries in Minimum Wages

In this section, we assume that minimum wages can be different between regions. We analyze how different minimum wages influence the location of firms. Figure 3 depicts the profit differential when the minimum wage in region A is fixed while the minimum wage in the other region is set at various levels. We focus on the most interesting case where $w^* > \widehat{w}$ and $\underline{w}_A > w^*$. This has already been partially analyzed in Figure 1.b where $\underline{w}_A = \underline{w}_B$. Extending the results to the other cases is straightforward.

Note first that the profit differential increases when the minimum wage $\underline{w}_B$ binds and rises. Indeed, for any ΔN, rising $\underline{w}_B$ increases the costs and decreases the profits in region B while it does not affect negatively the costs in the other region. This can readily be checked by inspection of (11). In Figure 3, this implies that curves $(1) - (7)$ are ranked by increasing order of $\underline{w}_B$. Also note that the minimum wage $\underline{w}_A$ binds in region A only for values of $\Delta N < \Delta N_2$.

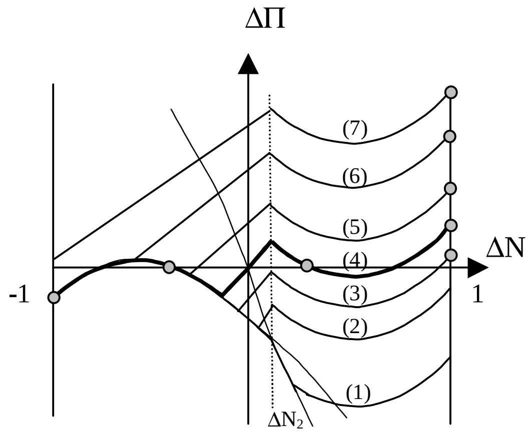

Figure 3

For very large values of $\underline{w}_B$ (curve (7)), the minimum wage binds in region B when $\Delta N > \Delta N_2$ and it binds in both regions otherwise. However, the profit is always larger in region A which makes full agglomeration in that region the unique stable equilibrium. For slightly lower $\underline{w}_B$ (curve (6)), the minimum wage ceases to bind in region B when many firms agglomerate in that region. Profits become larger in region B because of economies of agglomeration induced by the single cluster in that region. As a result full agglomeration in region B is a stable equilibrium. Full agglomeration in region A remains also a stable equilibrium. As the figure shows, a new stable equilibrium appears when the minimum wage $\underline{w}_B$ falls to a lower value (curve (5)). The size of the cluster in this partially asymmetric equilibrium is determined by the value of the minimum wage in region A: the larger $\underline{w}_A$, the more agglomeration in region B. When $\underline{w}_B$ still drops to a lower value (curve (4) which is similar to Figure 1.b), a second partially asymmetric stable equilibrium becomes possible. As Proposition 5 indicates, this happens when $\widehat{w} \leq \underline{w}_B \leq \widetilde{w}$. As $\underline{w}_B$ decreases, the partial agglomeration in region A is less important and disappears when $\underline{w}_B$ falls below w^* (as shown by curve (3)). For values of $\underline{w}_B$ that are lower than $\widehat{w}$, the profit differential becomes negative for full agglomeration in region A. Therefore, only two equilibria remain stable: partial agglomeration and full agglomeration in region B (see curves (2) and (1)). Note that for small values of $\underline{w}_B$, and for location patterns where ΔN is slightly larger than ΔN_2, wages become competitive in both regions (curve (1)).

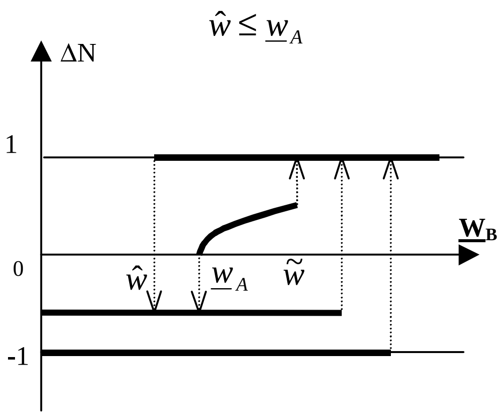

Figure 4.a

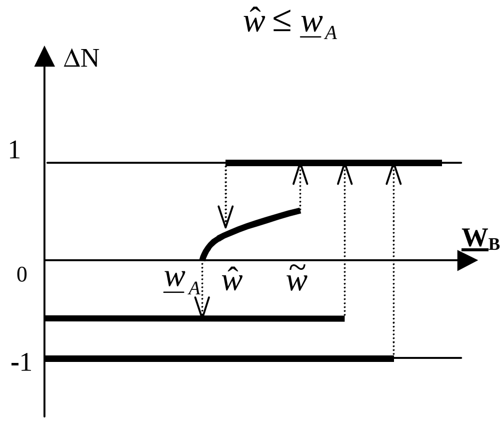

Figure 4.b

This analysis applies to countries or federations (e.g. the European Union) in which minimum wages are set by local institutions. History contributes to the selection of the location equilibrium and hysteresis effects also occur. These hysteresis effects are illustrated by Figure 4 in which the minimum wage in region B varies while that of the other region is kept constant above w^*. The location equilibria are presented by the bold lines. Note that the location asymmetry may not occur in the region with the lowest minimum wage. The dotted arrows depict the jumps between the different types of equilibria. In Figure 4.a the partial asymmetries in favor of region A completely disappear when the minimum wage is raised above $\widetilde{w}$ or when it is dropped below $\underline{w}_A$. *Once the economy has moved out of these partially asymmetric equilibria in region A, it never reaches them again.* It stays at full agglomeration in A or at partial agglomeration in B, or it may jump from one to the other. In Figure 4.b, partially asymmetric location equilibria in region A are always attainable when the minimum wage $\underline{w}_B$ is decreased below $\widehat{w}$. A further decrease below $\underline{w}_A$ induces a jump to partially asymmetric location in region B. Thus, by progressively decreasing the minimum wage in region B, *firms relocate to that region by steps.*

As mentioned above, this analysis can easily be extended to the cases where $\underline{w}_A < w^*$. The equilibria depicted in Figure 3 remain relevant except the partially asymmetric equilibrium in region B. As already shown in Figure 1.a, this equilibrium does not appear under equal minimum wages. This extends to asymmetries in minimum wages.

5 Concluding Remarks

In this paper, we build a simple model of an industry producing within two structurally symmetric regions. We include economies of agglomeration and labor markets in which workers do not move across regions. The core of the paper focuses on the impact of minimum wages on firms agglomeration. As mentioned in the introduction, the extension to reservation wages is straighfoward. In this section, we first summarize the results obtained for minimum wages. We then interpret these results in terms of reservation wages.

The presence of a minimum wage creates new location equilibria. On the one hand, one would expect that the introduction of a minimum wage smaller than the competitive wage would not alter the symmetry in firm location. However, we show that full agglomeration in a single (arbitrary) cluster may occur in that case. On the other hand, if the minimum wage is larger than the competitive wage, the symmetric location equilibrium becomes unstable: partially asymmetric location or full agglomeration in one region occur.

When the minimum wage or parameters of the model such as the global product demand vary, location equilibria move in a continuous way or jump from one type of equilibria to the other. The existence of jumps between multiple location equilibria generates hysteresis effects. Changes in minimum wage or in global product demand may induce irreversible changes in location equilibria. For instance, an increase in the minimum wage can move the equilibrium from partial asymmetry to full agglomeration. Nevertheless, setting the minimum wage back to its initial value would not restore the partial asymmetric equilibrium. This result holds whenever minimum wages are set by a central entity or by regional entities. When minimum wages differ between regions, the location asymmetry may not be in favor of the region with the lowest minimum wage.

Because reservation wages play the same role as minimum wages, similar agglomeration patterns and hysteresis effects occur. A rise in reservation wages or a decline in global product demand increases the likelihood of agglomeration. However, when agglomeration has occured, the reversal of these parameters to their initial values would not restore the previous equilibrium.

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