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Union wage demands with footloose firms

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Union Wage Demands with Footloose Firms and Agglomeration Forces[☆]

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Abstract

This paper analyses the wage demand of a sector-level monopoly union facing internationally mobile firms. A simple two-country economic geography model describes how firms relocate in response to international differences in production costs and market size. The union, in turn, sets wages as a function of the responsiveness of firms to relocate internationally. If the international differences in labour productivity and market size are limited then lower foreign wages and lower trade costs necessarily lead to lower union wage demands. If there exist large differences between the countries in terms of productivity and market size these intuitive properties do not always hold. Counter to intuition, small increases in market size or trade costs make the union wage more sensitive to foreign wages.

Key words: Unions, globalisation, economic geography JEL: J50, J31, F16

1. Introduction

After a period of spiralling inflation, rising labour costs, numerous firm closures and increasing unemployment the Belgian government decided to impose a nation-wide maximum yearly wage increase for sectoral labour agreements in 1988. It was hoped that such legislation would promote employment and pre-emptively secure the international competitiveness of

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the country. Since 1996 this maximum wage increase is calculated bi-yearly as an explicit function of the average wage evolution in the neighbouring countries. The view of wages as a strategic variable which can be used to attract foreign firms and increase employment raises many questions: is lowering wages instrumental to attract firms and increase employment? Does tying wages to the foreign level of wages secure employment? Does globalisation imply that wages have to be lowered in order to preserve employment?

Such questions are immaterial in classical models of international trade as they mostly rely on perfect product and labour markets where there are no firm profits and wages are purely competitive. Starting with Brander and Spencer (1988) and Mezzetti and Dinopoulos (1991), however, quite a few authors have analysed unionised labour markets in the context of oligopolistic competition with immobile firms, allowing for FDI as in the model of Konings and Vandenbussche (1998), or within a monopolistic competition framework such as Andersen and Sørensen (2000) and related papers. The effect of falling trade costs on wages is a central research question in this strand of literature, such as for Naylor (1999) who considers the effect of falling trade costs on the international Nash-equilibrium when wage bargaining occurs simultaneously in two symmetric countries.

Picard and Toulemonde (2003, 2006), De Bruyne (2004) and Munch (2003), among others, consider the effects of unionisation on the location choice of firms within economic geography models. In this paper we also use a 'new economic geography' (NEG) model with perfectly mobile firms, but rather focus on how the firms' location choice affects union wage demands. We start from a simple NEG model explaining where firms locate in response to international differences in market access, wages, labour productivity and trade costs. Unions fully take into account how their wage demands affect firm level labour demand and the international distribution of firms. Trade openness and other parameter changes affect the sensitivity of firms to relocate in response to international wage differences, which changes aggregate labour demand elasticity and therefore union wage demands.

The fact that unions are explicitly aware of the possibility of firm relocation makes our model quite different from a part of the existing literature on union behaviour with internationally mobile firms. In models such as Picard and Toulemonde (2003, 2006), unions take the location of firms as given, with firms choosing location before unions set wages. Although this approach seems reasonable given the longevity of capital investment compared to the duration of a typical wage agreement, it may lead to situations where unions make wage demands which exceed the level at which any firm would locate in the country. It seems implausible that unions are unable to commit at all to wage levels which are acceptable to at least some firms, especially

in a context where unions are organised at the sector level as in most European countries. The traditional European sector-level union is a stable organisation with a long time-horizon, and may act as a vehicle for strategic delegation by individual union members in order to aid commitment (Jones, 1989). These unions are at times so well organised that they see short-sightedness, defections and the lack of organisation and commitment on the employers side as problematic, rather than the other way around[2]. When organised at the sector level, even short sighted unions should be aware that at any point in time at least a fraction of firms in the sector will be at the end of an investment cycle, such that some relocation will occur in response to wage increases. Moreover, if firms value future profits highly, then even with long-lived fixed localised investment where relocation would hurt the firm in the short-run, the threat of relocation becomes credible and relevant even to extremely myopic unions (see Espinosa and Rhee, 1989; Addison and Chilton, 1998). One example of such a strategy may be the decision of the Spanish car manufacturer SEAT (part of Volkswagen) to partially relocate the production of the SEAT Ibiza model from Martorell in Spain to Bratislava in Slovakia in 2003 after failed negotiations with unions. This move has been widely perceived as 'punishment' of the local unions, and has even been described literally as such in an internal market-study of the rival car producer Renault which was leaked to the press. Examples are abound of firms relocating or considering relocation in search of lower production costs, and these threats are often used during the collective bargaining process (see, for example, the surveys of Eurofound, 2010). It is hard to imagine that the observed relocation of firms, or just the presence or perception of a threat of firm relocation, does not affect union behaviour. Unions therefore are assumed to explicitly take into account the international mobility of firms in this paper.

Through the economic geography approach our model is also related to models of international tax competition with mobile firms such as for example Ludema and Wooton (2000), Andersson and Forslid (2003) and Baldwin and Krugman (2004). In these models a government has to strike a balance when increasing taxes, as some of the tax base is lost when firms start relocating in response. When all firms prefer to locate in a single country where they earn higher profits, however, the gap between local profits and the lower potential foreign profits allows a government to tax without causing relocation. Similarly, in our model, if all firms prefer to locate in a single country, the existence of an international profit differential allows wages to be increased up to a certain level without causing firm relocation.

But a union acting on the sector level might find it optimal to set higher wages despite the

[2]See, for example, the article by IG Metal president Klaus Zwickel in the *Frankfurter Allgemeine Zeitung* of April, 6, 1995 and the discussion in Thelen (2000).

resulting relocation of some firms. We show that the exact wage demand then depends on how many firms relocate for a given wage change.

Through the introduction of a simple NEG model we are able to quantify both the 'wage elasticity of firm relocation' and the size of the international profit differential which determine union wage demands in case both countries contain firms and in case all firms locate in a single country, respectively.

A key question we address using this model is whether lower trade costs necessarily lead to lower union wage demands. We find that this intuition only holds if the differences between both countries in terms of labour productivity and market size are small. For asymmetric countries, a larger market size or the existence of a comparative advantage can induce all firms to agglomerate in a single country. With full agglomeration, firm relocation no longer assures profits are equalised internationally and the resulting international profit differential is appropriated by the union in the form of higher wages. Locating in a country with a relatively large market size is especially interesting for firms at intermediate levels of trade freeness. It is shown that the international profit differential is a hump-shaped function of trade freeness when all firms locate in the larger country, and therefore union wages are a hump-shaped function of trade freeness in this case. If a country is able to attract the industrial core because of a comparative advantage rather than a market size advantage, lower trade costs will imply that the country becomes an increasingly attractive location for firms, and the wages which unions can charge without causing any firm to relocate therefore increase with freer trade. But even when both countries contain firms, union wage demands may increase after trade liberalisation: trade liberalisation may decrease the sensitivity of the international distribution of firms to wage changes and therefore leads to higher union wage demands.

Another counter-intuitive prediction of the model is that an exogenous decrease in the level of foreign wages does not necessarily lead to lower local union wage demands. Although lower foreign wages cause some firms to relocate as long as both countries contain firms, the marginal propensity of firms to relocate may then actually decrease, leading to a lower aggregate labour demand elasticity and higher optimal union wage demands in the remaining local firms.

Moreover, it turns out that, at least for small changes around the symmetric case with identical countries, union wages in larger, more closed countries are *more* sensitive to the foreign wage level. The reason is that, although the 'direct' effect of a larger market size or higher transport costs is to make union wages less sensible to foreign wage changes, these changes also induce unions to increase their wage demands. As higher wages are more sensitive to foreign wage changes, the total effect turns out to make union wages more sensitive to

changes in the foreign wage level.

This paper consists of three sections after the introduction. Section 2 introduces a simple two-country NEG model where wages in both countries are taken as given. We consider the effect of exogenous wage changes on firm profits and the equilibrium international distribution of firms. In section 3 wages are set by a monopoly union which fully takes into account the results on firm behaviour. We determine how union wage demands react to changes in transport costs, foreign wages, and market size; and how the sensitivity of union wage demands with respect to foreign wage changes is affected by the market size of a country and the level of trade costs. A final section concludes.

2. A simple two-country NEG model

In this section we adapt the two-country footloose-capital model of Martin and Rogers (1995), allowing for international differences in wages and labour productivity. We establish how firms relocate in response to changes in the manufacturing wage, under which conditions all firms agglomerate in a single country and determine the international profit differential (the agglomeration rents) which may result if this occurs. Throughout this section we take wages in both countries as given.

2.1. Model setup

There are two countries, H and F. As in Pflüger (2004) the utility function V of the representative consumer in both countries is quasi-linear in the consumption of a homogeneous good C_A, and a CES-composite C_M of a continuum of differentiated manufacturing varieties indexed by i and consumed in quantities $q(i)$. A mass of n^w of such manufacturing varieties is produced worldwide. We assume

$$V = C_A + \mu \ln(C_M) \qquad C_M = \left(\int_{i=0}^{n^w} q(i)^{\frac{\sigma-1}{\sigma}} \, di \right)^{\frac{\sigma}{\sigma-1}},$$

where parameter $\mu > 0$ expresses the consumer preference for manufacturing goods relative to the homogeneous good, and $\sigma > 1$ is the elasticity of substitution between manufacturing varieties. Choosing the A-sector good as the numéraire implies $p^A = 1$. Constrained utility maximisation gives rise to a simple individual demand function for the CES-composite $C_M = \mu P_k^{-1}$, where $P_k = \left[\int_{i=0}^{n^w} p(i)^{1-\sigma} di \right]^{\frac{1}{1-\sigma}}$ is the price-index of manufacturing goods consumed in country k, with $p(i)$ the price of manufacturing variety i. Per-consumer expenditure on manufacturing goods therefore equals μ. The individual consumer demand for the homogeneous good is the residual of the individual income after subtracting expenditures on manufacturing goods, or

$C_A = Y - \mu$. From the point of view of a consumer in country k, some of the manufacturing varieties are produced locally and some are imported, as long as both countries contain some manufacturing firms. Denote the quantity of a manufacturing variety i which is produced in country j and sold in country k by $q_{jk}(i)$. The demand of the representative consumer in country k for such a variety which is sold at a consumer price of $p_{jk}(i)$ then is simply

$$q_{jk}(i) = \frac{\mu}{P_k}\left(\frac{p_{jk}(i)}{P_k}\right)^{-\sigma} \qquad j,k \in \{H,F\}. \tag{1}$$

Note that because of the quasi-linear utility specification, the demand for manufacturing goods of the typical consumer does not depend on her income. Total demand in country k is simply the demand of the typical consumer times the exogenously given mass of consumers M_k in the country.

The homogeneous good sector A is kept as simple as possible. A-sector firms use a constant returns to scale technology with labour as the sole input. Both countries are assumed to produce some of the A-good in equilibrium. This will be the case if world-wide demand for it is sufficiently large compared to the labour supply in each country. Countries may have different labour productivities. $1/\alpha_j^A$ is the quantity of labour required in country j to obtain one productivity-equivalent unit of labour and w_j^A is the reward to labour. Perfect competition in the A-sector leads to marginal cost pricing. Assuming costless trade implies that prices, and therefore marginal costs, are equalised internationally. Since the A-sector good was chosen as the numéraire ($p^A = 1$), the result is productivity-adjusted international wage equalisation for labour employed in the A-sector:

$$\frac{w_H^A}{\alpha_H^A} = \frac{w_F^A}{\alpha_F^A} = p^A = 1 \qquad \text{or} \qquad w_H^A = \alpha_H^A \;\text{ and }\; w_F^A = \alpha_F^A. \tag{2}$$

Unlike the A-sector firms, a manufacturing firm in country j faces a fixed cost in that it requires a single unit of capital at price r_j irrespective of the output level. For the variable part of production $1/\alpha_j$ units of labour are required per unit of output. There is imperfect mobility of workers between sectors, such that wages in both sectors may differ. Manufacturing wages are given by w_H, and $w_H \geq w_H^A$ is assumed throughout. In the next section the union will be shown to optimally set wages such that this inequality holds. The CRS sector absorbs all labour which is not hired by the manufacturing firms. Writing w_j for the manufacturing wage in country j, the representative country j manufacturing firm's cost for producing x units of

output is

$$C_j(x) = r_j + \frac{w_j}{\alpha_j} x.$$

The ratio w_j/α_j corresponds to the labour cost of producing one extra unit of manufacturing output, the manufacturing unit labour cost in country j.

Manufacturing firms operate under monopolistic competition. Profit maximisation implies that firms set consumer prices at a constant mark-up $\eta = \frac{\sigma}{\sigma-1}$ over marginal costs. Assuming symmetric iceberg transport costs $\tau > 1$ for selling abroad, exports are subject to higher marginal costs and subsequently are sold at a proportionally higher consumer price. The consumer price $p_{jk}(i)$ charged by the representative manufacturing firm located in country j for sales in country k then is

$$\begin{aligned} p_{jj}(i) &= \eta w_j/\alpha_j & j &\in \{H,F\} & \text{(local sales)} \\ p_{jk}(i) &= \tau\eta w_j/\alpha_j = \tau p_{jj}(i) & j,k &\in \{H,F\},\ j \neq k & \text{(exports)}, \end{aligned} \tag{3}$$

As all firms i located in country j charge the same price $p_{jk}(i) = p_{jk}$ for sales in country k, the argument i will be dropped where possible. Since the demand for all manufacturing varieties sold at the price p_{jk} is identical, we similarly write q_{jk}. Without loss of generality, the mass of capital (and thus the mass of firms and manufacturing varieties) is normalised to one ($n^w = 1$). Write n for the mass of varieties produced in H, which corresponds to country H's share of manufacturing firms worldwide. The share and mass of varieties produced in F then is $1-n$. Furthermore, we introduce $\phi \equiv \tau^{1-\sigma}$ as the standard measure of 'trade freeness' which is inversely related to the iceberg transport costs τ, and is bounded between 0 (autarky) and 1 (free trade). Moreover, it will be useful to use $c \equiv \left(\frac{w_H}{\alpha_H}\Big/\frac{w_F}{\alpha_F}\right)^{\sigma-1}$ as a measure of the relative unit labour costs of country H. A higher level of c corresponds to higher relative unit labour costs in country H.

The manufacturing price index $P_k = \left[\int_{i=0}^{1} p(i)^{1-\sigma} di\right]^{\frac{1}{1-\sigma}}$ in both countries can then be written as

$$\begin{aligned} P_H &= \left[\int_0^n p_{HH}(i)^{1-\sigma}\, di + \int_n^1 p_{FH}(i)^{1-\sigma}\, di\right]^{\frac{1}{1-\sigma}} \\ &= \left[n(\eta w_H/\alpha_H)^{1-\sigma} + (1-n)(\tau\eta w_F/\alpha_F)^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \\ &= \eta\frac{w_H}{\alpha_H}\left[n + c\phi(1-n)\right]^{\frac{1}{1-\sigma}}, \\ P_F &= \eta\frac{w_H}{\alpha_H}\left[\phi n + c(1-n)\right]^{\frac{1}{1-\sigma}}. \end{aligned} \tag{4}$$

The price indices are composed of a term stemming from sales of domestic firms and a term stemming from imports. These are weighted by the share of firms in each country (there are n firms in H and $1-n$ firms in F), the parameter of trade freeness ϕ for imports, and c reflecting the relative production costs.

Given the above pricing rules and taking into account that, due to iceberg transport costs, τx units of output have to be produced to sell x units abroad, a firm's operating profits are proportional to total production:

$$\pi_j = p_{jj}x_{jj} + \tau p_{jj}x_{jk} - \frac{w_j}{\alpha_j}(x_{jj} + \tau x_{jk}) = \frac{p_{jj}(x_{jj} + \tau x_{jk})}{\sigma}. \tag{5}$$

Given the fixed supply of capital its reward is bid up to the point where all these operating profits accrue to capital. Writing r_j for the return to capital in country j it therefore holds that $r_j = \pi_j$.

There is a total of $(M_H + M_F = M_W)$ consumers worldwide. The number of consumers in both countries is assumed to be fixed, but not necessarily equal. Because per capita expenditure on manufacturing is fixed as a result of the quasi-linear utility specification, the expenditure on manufacturing goods in country H relative to world manufacturing consumption equals its share of consumers: $m = M_H/M_W$. Given the immobility of consumers, the share of manufacturing expenditure in a country is exogenous. Normalising the world mass of consumers $M_W = 1$, the market share of H is m and $1-m$ for country F. Throughout, both countries are assumed to contain at least some consumers, or $0 < m < 1$.

Using expression (5) for the return to capital $r_j = \pi_j$ in country j, substituting the optimal pricing rules from equation (3), consumer demand from equation (1), and the expression (4) for the manufacturing price indices in both countries, the return to capital in both countries is given by:

$$\begin{aligned} r_H &= \frac{\mu}{\sigma}\left[\frac{m}{\Delta_H} + \phi\frac{1-m}{\Delta_F}\right] \qquad & \Delta_H &= n + \phi c(1-n) \\ r_F &= \frac{\mu}{\sigma}c\left[\phi\frac{m}{\Delta_H} + \frac{1-m}{\Delta_F}\right] \qquad & \Delta_F &= \phi n + c(1-n). \end{aligned} \tag{6}$$

Capital is mobile and is relocated to the country with the highest return. Capital owners, in contrast, are assumed to be immobile and consume repatriated profits locally. As a standard assumption of monopolistic competition, capital owners do not take into account the effect of their actions on the manufacturing price index or the general price level. These assumptions imply that capital owners compare the nominal returns to capital between both countries when

making investment decisions.

Capital relocation will take place until the returns to capital are equalised in both countries ($r_H = r_F$) or until all firms agglomerate in a single country. If capital returns are equalised with both countries containing firms ($0 < n < 1$) this defines a long-run interior equilibrium. When all capital is located in a single country ($n = 0$ or $n = 1$) this defines a corner solution. The next two sections discuss the case of interior equilibria and corner solutions separately.

2.2. Interior equilibrium

This section considers the case where both countries contain firms in equilibrium, such that $0 < n < 1$.

Equating the expressions for the return to capital in both countries from equation (6) and solving for n, we obtain the unique interior long-run equilibrium distribution of capital, and the condition for its existence:

$$n = c\frac{(1-\phi^2)m - \phi(c-\phi)}{(c-\phi)(1-c\phi)} \qquad \text{if} \qquad \frac{\phi}{1-m(1-\phi^2)} < c < \frac{\phi^2 + m(1-\phi^2)}{\phi}. \tag{7}$$

As the condition shows, an interior equilibrium occurs if the production costs differential between both countries is not too large relative to the freeness of trade ϕ. Perfectly free trade is in general incompatible with an interior equilibrium, and therefore $\phi < 1$ is assumed throughout this section. It can easily be verified that the condition for an interior equilibrium implies $1 - c\phi > 0$ and $c - \phi > 0$ and these weaker conditions often turn out to be sufficiently strong to sign expressions.

Following results can easily be derived:

$$\frac{\partial n}{\partial m} = \frac{c(1-\phi^2)}{(c-\phi)(1-c\phi)} \geq 1$$
$$\frac{\partial n}{\partial c} = -\frac{\phi\left[(c-\phi)^2 + (1-c^2)(1-\phi^2)m\right]}{(c-\phi)^2(1-c\phi)^2} \leq 0,$$

and the following proposition can be shown to hold:

Proposition 1. *For interior solutions ($0 < n < 1$) and with exogenous wages, it holds that:*

In autarky ($\phi = 0$), the share of manufacturing firms equals the market share ($n = m$). The share n then is insensitive to the relative labour cost c and increases proportionally with its market size m. For $\phi > 0$, the share of manufacturing firms decreases with higher labour costs c ($\partial n / \partial c < 0$) and increases more than proportionally with market size ($\partial n / \partial m > 1$).

Figure 1 illustrates how the international distribution of firms n depends on the relative market size m (left panel) and relative production costs c (right panel). The left panel assumes away international production cost differences ($c = 1$) while in the right panel the countries are assumed to be of equal size ($m = 1/2$). As can be learned from equation (7), at $\phi = 0$ the share of firms in a country equals its market share, or $n = m$, and therefore $\frac{\partial n}{\partial m}\Big|_{\phi=0} = 1$ and $\frac{\partial n}{\partial c}\Big|_{\phi=0} = 0$. For $0 < \phi < 1$, however, it holds that $\frac{\partial n}{\partial c} < 0$ and $\frac{\partial n}{\partial m} > 1$: an increase in the production costs of a country decreases its share of firms, and an increase in the market share of a country leads to a *more than proportional* increase in a country's share of manufacturing. This property is typical of models of economic geography and is commonly known as 'home-market magnification'. In both panels of figure 1, trade freeness is set at $\phi = 0.15$ and therefore the share of firms in country H rises more than proportionally as a function of m in the left panel. Note that in the right panel of figure 1, the curve of n is steeper at low or high relative

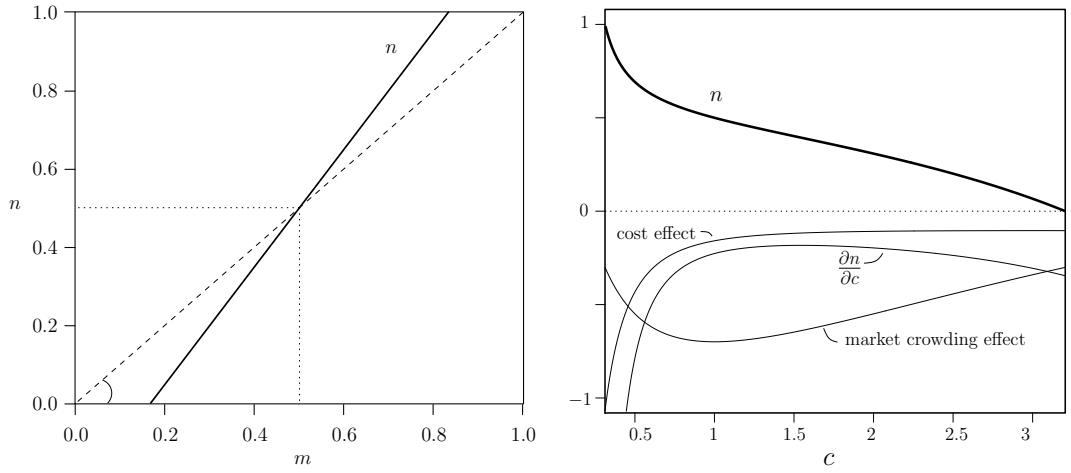

Figure 1: The effect of the relative market size (left panel) and production costs (right panel) on a country's share of manufacturing firms. The left panel assumes equal production costs in both countries ($c = 1$), while in the right panel the market size is assumed to be equal in both countries ($m = 1/2$).

production costs, compared to more moderate levels of c, where the slope of $\partial n / \partial c$ is smaller. This will play an important role for the optimal union wage determination in section 3.

The non-monotonicity of $\partial n / \partial c$ can be understood by studying the underlying forces of the model. Totally differentiating the profit differential $\Delta' = r_H - r_F = 0$, keeping all variables fixed except for relative production costs c, the market share m and the distribution of firms n, shows that

$$d\Delta' = d(r_H - r_F) = \frac{\partial \Delta'}{\partial c} dc + \frac{\partial \Delta'}{\partial m} dm + \frac{\partial \Delta'}{\partial n} dn = 0.$$

Here, $\frac{\partial \Delta'}{\partial n} < 0$ expresses by how much the difference in profits between H and F changes[3] given an exogenous change in the share of firms n in country H. The negative effect of an increase in the number of firms on firms profits (or the profit differential in this case) is therefore commonly called the 'market-crowding effect'. Similarly, $\frac{\partial \Delta'}{\partial m} > 0$ is known as the 'market access effect' and we will refer to $\frac{\partial \Delta'}{\partial c} < 0$ as the relative production cost effect or just 'cost effect'. In the right panel of figure 1, both countries are equally large ($m = 1/2$), such that only the market crowding effect and the cost effect play a role. Since both these effects are negative, an increase in c must lead to an decrease in n to restore the equality of profits in both regions, for interior equilibria. The increase in n which restores the equality of profits after a change in c is given by $\frac{\partial n}{\partial c} = -\frac{\partial \Delta'}{\partial c} \Big/ \frac{\partial \Delta'}{\partial n} < 0$.

Although the exact expressions for the market access effect $\frac{\partial \Delta'}{\partial m} > 0$ and the market crowding effect $\frac{\partial \Delta'}{\partial n} > 0$ are complex, it can be shown that the market crowding effect is strongest (most negative) at $c = 1$, irrespective of any market size asymmetries or the distribution of firms. The production cost effect, in contrast, becomes smaller in absolute value as c increases. If the decrease in the strength of the market crowding effect for values $c > 1$ is sufficiently large compared to the decreasing production cost effect, the sensitivity of the distribution of firms with respect to changes in relative production costs will reach a minimum. Such a minimum of $\partial n / \partial c$ can be shown to exist under the relatively weak condition that the market size is relatively evenly distributed between both countries, such that $\frac{\phi}{1+\phi} < m < \frac{1}{1+\phi^2}$. The expression for the level of c where $\partial n / \partial c$ reaches a minimum in absolute value is complicated, but it is always larger than $c = 1$, where production costs are equal in both countries. It equals $c = (1 + \phi^{4/3})/(\phi^{1/3} + \phi)$ in case $m = 1/2$, as in the right panel of figure 1. Here, $\phi = 0.15$ such that the minimum of $\partial n / \partial c$ is reached around $c = 1.6$.

The effect of the trade freeness parameter ϕ on the interior distribution of firms n depends on the direction of production cost and market size asymmetries.

$$\frac{\partial n}{\partial \phi} = c \frac{\left(4c\phi(1-\phi^2) - \phi^2\right)\left(\frac{1}{2} - m\right) + m(1-c^2) - c^2}{(c-\phi)^2(1-c\phi)^2} \tag{8}$$

If $c < 1$, freer trade (increases in ϕ) always leads to an increase in n. If $c > 1$, but H has a sufficient size advantage relative to its cost handicap such that $m > c^2/(1+c^2)$, firms initially increasingly locate in H for higher ϕ. For sufficiently high ϕ, however, firms eventually relocate

[3] For $\phi < 1$, an increase in the number of firms located in a country (keeping everything else constant) lowers the profits of firms, since more competing manufacturing varieties are sold locally at prices which do not include transportation costs.

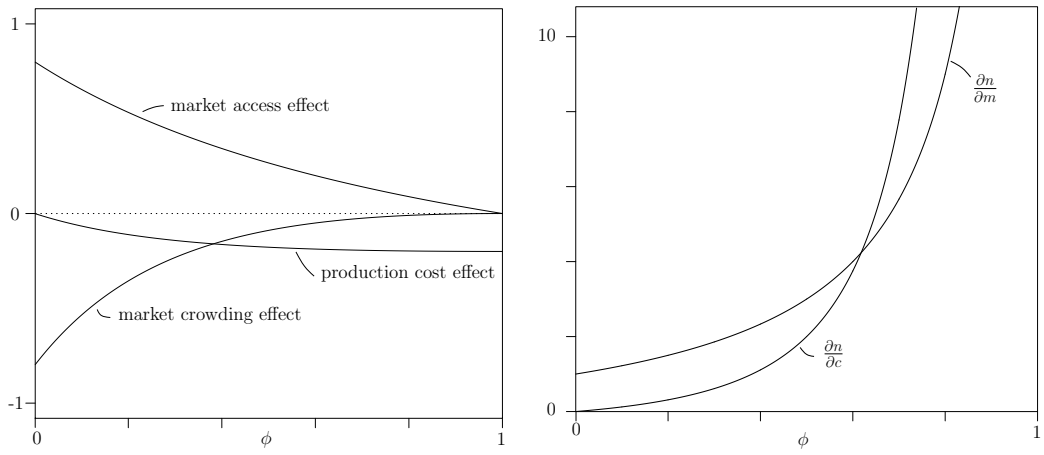

Figure 2: The effect of ϕ on the three forces of the model (left panel) and the sensitivity of the distribution of firms n to changes in market size m and production costs c. Both panels are drawn for the case of small deviations in m, c and n around the symmetric equilibrium $m = \frac{1}{2},\ c = 1,\ n = \frac{1}{2}$.

toward the low cost country. More generally, following proposition can be shown to hold:

Proposition 2. *For interior solutions and exogenous wages, it holds that:*

The share of firms in a large, low cost country always increases with freer trade. The share of firms in a small, high cost country always decreases with freer trade.

There exists a range of trade freeness where a large high-cost country attracts an increasing share of firms when trade becomes freer, provided its market is sufficiently large compared to its cost handicap. The condition is $m > c^2/(1+c^2)$ for country H.

There exists a level of $\phi < 1$ above which firms increasingly locate toward the low-cost country irrespective of any market size asymmetry.

These properties of the effect of ϕ on n can be best understood by considering how ϕ affects the underlying forces in the model around the symmetric equilibrium[4] ($m = 1/2,\ c = 1,\ n = 1$). As can be seen in the left panel of figure 2, the market access and market crowding effect are equally large at $\phi = 0$. Indeed, at $\phi = 0$ we have $n = m$ and $\frac{\partial n}{\partial m} = -\frac{\partial \Delta'}{\partial m} \Big/ \frac{\partial \Delta'}{\partial n} = 1$. As trade costs decline, both the stabilising market crowding effect and the market access effect decrease. The market crowding effect declines faster than the market access effect, however, and as trade becomes freer, a more than proportional and ever larger shift in the number of firms will therefore be required to restore the equilibrium for a given change in the market share m. This increase in the partial effect of a change in m on n in equilibrium $\frac{\partial n}{\partial m} = -\frac{\partial \Delta'}{\partial m} \Big/ \frac{\partial \Delta'}{\partial n}$ is illustrated

[4] At the symmetric equilibrium ($m = 1/2,\ c = 1,\ n = 1$) these forces reduce to simple expressions: $\frac{\partial \Delta'}{\partial c} = -\frac{4\phi}{(1+\phi)^2}\frac{\mu}{\sigma}$ for the production cost effect, $\frac{\partial \Delta'}{\partial n} = -\frac{4(1-\phi)^2}{(1+\phi)^2}\frac{\mu}{\sigma}$ for the market crowding effect and $\frac{\partial \Delta'}{\partial m} = \frac{4(1-\phi)}{(1+\phi)}\frac{\mu}{\sigma}$ for the market access effect.

in the right panel of figure 2. In contrast to the market access and market crowding effects, at $\phi = 0$ the relative production costs are irrelevant to the profit differential and therefore the equilibrium distribution of firms. The strength of the production cost effect slowly but steadily increases for higher ϕ (left panel), however. Because the production cost effect $\frac{\partial \Delta'}{\partial c}$ becomes stronger with freer trade and the market access effect $\frac{\partial \Delta'}{\partial m}$ becomes weaker, the corresponding partial effect of changes in relative production costs on the equilibrium distribution of firms $\partial n / \partial c = -\frac{\partial \Delta'}{\partial c} \Big/ \frac{\partial \Delta'}{\partial n}$ increases faster than the effect of change in the relative market size $\partial n / \partial m = -\frac{\partial \Delta'}{\partial m} \Big/ \frac{\partial \Delta'}{\partial n}$ when trade trade costs becomes very low (right panel).

If H has a production cost advantage, both the cost effect and the market access effect work to increase the number of firms in the country, and increasingly will do so as trade costs decline. Similarly, a small country with a production cost handicap will always lose firms as ϕ increases. As the production cost effect remains small for low values of ϕ and the market access effect is relatively large and increasing in ϕ, a sufficiently large country will be able to attract an increasing number of firms as ϕ increases, even in presence of a (sufficiently small) production cost handicap. The exact condition is $m > c^2/(1+c^2)$ for country H. The small increase in the cost effect for low ϕ will not matter greatly to firm location if the production cost handicap is small. For larger ϕ, in contrast, the production cost effect will start to dominate. There always exists a level[5] of $\phi < 1$ above which firms increasingly locate toward the low-cost country irrespective of any market size asymmetry, and, as will be discussed in the next section, there necessarily exist a level of $\phi < 1$ at which all firms locate in the low-cost country.

2.3. Corner solutions

As H's share of firms n is strictly decreasing in its labour costs if $\phi > 0$ and the world supply of capital (and thus firms) is limited, there may exists a critical level c^{CH} of labour costs c below which all firms find it optimal to locate in H. Solving $n = 1$ for c shows that the condition for all firms to locate in H is given by

$$c \leq c^{CH} \equiv \frac{\phi}{1 - m(1-\phi^2)}, \tag{9}$$

Where the superscript Cj is used to denote a critical level of a parameter or variable at which country j is able to attract the industrial core. This critical value of c^{CH} equals 1 if $\phi = 1$: for

[5] If $m > c^2/(1+c^2)$ such that country H is sufficiently large to attract an increasing number of firms for some levels of ϕ, but $c > 1$ such that H has a relative production cost handicap, firms will start relocating to F (or $\partial n / \partial \phi < 0$) for ϕ larger than $\phi^* = \left(2c(\frac{1}{2} - m) + \sqrt{(1-c^2)^2(1-m)m}\right) / \left(m(1+c^2) - 1\right) < 1$.

perfectly free trade only the international production cost differential c matters to firms, and all firms will locate in H if its production costs are even slightly lower compared to country F ($c < 1$). If $\phi = 0$, in contrast, $c^{CH} = 0$. The share of firms then is solely determined by its relative market share ($n = m$) and there does not exist[6] a level of relative production costs (and thus wages) which induces all firms to locate in H. Condition (9) can be written in function of ϕ, from which it is found that the condition for full agglomeration in H is $\phi \in [\phi^{CH1}, \phi^{CH2}]$ with

$$\phi^{CH1} \equiv \frac{1 - \sqrt{1 - 4c^2 m(1-m)}}{2cm} \qquad \text{and} \qquad \phi^{CH2} \equiv \frac{1 + \sqrt{1 - 4c^2 m(1-m)}}{2cm}.$$

If $c < 1$, the lower critical value ϕ^{CH1} is smaller than one and the upper critical value ϕ^{CH2} is larger than one (and therefore irrelevant). All firms then remain in the low-cost country H for $\phi^{CH1} < \phi \leq 1$. If $c > 1$ and $m - \frac{1}{2} < \frac{\sqrt{c^2-1}}{2c}$, both critical values are irrelevant, as the relative market size and production costs of H make it impossible for H to attract the industrial core for any level of trade freeness. If $c > 1$ and $m - \frac{1}{2} > \frac{\sqrt{c^2-1}}{2c}$, the market size advantage of H is sufficiently large as to attract all firms for intermediate levels of $\phi \in [\phi^{CH1}, \phi^{CH2}]$ and both these critical values then become relevant.

A critical value of c above which all firms agglomerate in F ($n = 0$) can be determined following the same steps:

$$c > c^{CF} \equiv \frac{\phi^2 + m(1-\phi^2)}{\phi}.$$

It also holds that $c^{CF} = 1$ when $\phi = 1$, and $c^{CF} = 0$ when $\phi = 0$: for perfectly free trade higher production costs in H ($c > 1$) imply agglomeration in F irrespective of relative market sizes; in autarky, country F can never attract the manufacturing core, since the share of firms in both countries equals the market share, irrespective of any production cost difference. Critical values in terms of ϕ for the case of full agglomeration in F can be easily derived but are omitted here. An intermediate level of trade freeness for which all firms locate in F in spite of a production cost handicap ($c < 1$) exists if its market size is sufficiently large such that $m - \frac{1}{2} < \frac{\sqrt{1-c}}{2}$.

Following proposition summarises the results on the critical values for full agglomeration.

Proposition 3. *If asymmetries are sufficiently large compared to transportation costs, full agglomeration occurs. With* $c < c^{CH} \equiv \frac{\phi}{1-m(1-\phi^2)}$ *all firms agglomerate in H. If* $c > c^{CF} \equiv \frac{\phi^2+m(1-\phi^2)}{\phi}$ *all firms agglomerate in F.*

[6]Note that both countries are assumed to contain at least some consumers such that $0 < m < 1$ and $0 < 1 - m < 1$.

All equations and propositions relating to interior solutions are valid only if both countries contain firms, or $c^{CH} < c < c^{CF}$. It can be easily verified that $c > c^{CH}$ implies $1 - c\phi > 0$ and $c < c^{CF}$ implies $c - \phi > 0$. These conditions are weaker, but often turn out to be sufficiently strong to sign expressions.

Sometimes critical values in terms of absolute levels of wages rather than relative unit labour costs will be needed. Writing w_H^{CH} for the level of w_H for which all firms agglomerate in country H and using the definition of $c \equiv (\alpha_F w_H / \alpha_H w_F)^{\sigma-1}$ the condition for full agglomeration in H $c < c^{CH}$ holds if $w_H < w_H^{CH} \equiv \frac{\alpha_H w_F}{\alpha_F}(c^{CH})^{1/(\sigma-1)}$.

2.4. The wage elasticity of the international firm distribution

For interior equilibria, increasing relative production costs decrease a country's share of firms. Increasing local wages will increase the relative production costs and it is convenient to express how fast small changes in wages cause international relocation of firms in terms of an elasticity. For the elasticity of the share of firms in H with respect to changes in manufacturing wages in H, we define

$$\epsilon_{\text{reloc}} \equiv \frac{\partial n}{\partial w_H}\frac{w_H}{n} = (1-\sigma)\frac{m(1-\phi^2)(1-c^2)+(c-\phi)^2}{(c-\phi)(1-c\phi)(c^{CF}-c)} < 0, \quad \text{if} \quad 0 < n < 1. \tag{10}$$

When wages in H are increased up to the point where c approaches the level c^{CF} at which all firms relocate to country F, ϵ_{reloc} tends to minus infinity as the elasticity expresses $\partial n / \partial w_H < 0$ relative to an ever smaller base of remaining firms n. From now on we refer to the positive number $|\epsilon^H_{\text{reloc}}|$ as the elasticity of relocation. A similar expression can be written for changes in w_F from the point of view of the foreign country.

The elasticity of relocation will be key to the wage setting decision of the union in section 3.

2.5. Agglomeration rents

When all firms locate in a single country this prevents relocation to act as corrective arbitrage, and hence potential firm profits may differ between countries. The resulting international profit gap or agglomeration rents play an important role for the union when determining the optimal wage demand. Taking the ratio of capital rents in both countries from equation (6), we can conveniently express the agglomeration rents for a firm located in country H as

$$\begin{aligned} z_H \equiv r_H / r_F = \tfrac{\phi}{c(1-m+\phi^2 m)} = c^{CH}/c \qquad & \text{if} \quad n = 1 \\ z_H \equiv r_H / r_F = 1 \qquad & \text{if} \quad 0 < n < 1. \end{aligned} \tag{11}$$

The agglomeration rents in H are higher, the lower relative unit labour costs c are relative to the critical level where all firms agglomerate in H, c^{CH}. In the knife-edge case $c = c^{CH}$ and for interior equilibria, firms earn equal profits in both countries, firms are indifferent between locations and there are no agglomeration rents, or $z_H = 1$. Some comparative statics of the agglomeration rents in the core-periphery configuration $n = 1$ will prove useful in the next section on the union wage demands:

$$\frac{\partial z_H}{\partial c} < 0 \qquad \frac{\partial z_H}{\partial m} > 0 \qquad \frac{\partial z_H}{\partial \phi} = \frac{1 - m(1+\phi^2)}{c[1-m(1-\phi^2)]^2}.$$

The first two results are not surprising: as firms are attracted by low production costs and large markets, the agglomeration rents in H are decreasing in c and increasing in m. The third result shows that z_H is monotonically increasing in ϕ if $m \leq 1/2$, but is hump-shaped with a top at $\phi^* = \sqrt{(1-m)/m}$ if $m > 1/2$. Note that a smaller country can only attract the core if it has lower production costs. It is intuitive that agglomeration rents stemming from a market size advantage are a bell-shaped function of trade freeness: at low levels of trade freeness the share of firms in a country approximately equals its market share. Deviations from this equilibrium are per definition not profitable. If trade is very free, firms are indifferent about their location relative to the distribution of consumers, as goods are transported to wherever consumers are at a low cost. Only for intermediate levels of trade freeness it is profitable for all firms to agglomerate in the largest market. This is very different for agglomeration rents stemming from a production cost advantage: firms increasingly prefer to locate in a low-cost country as trade becomes freer.

Following proposition summarises the results on the effect of trade freeness on agglomeration rents:

Proposition 4. *If a relatively small or equally sized low-cost country attracts all firms, agglomeration rents are monotonically increasing in the freeness of trade. If the larger country contains the core, agglomeration rents are a hump-shaped function of ϕ and reach a maximum at $\phi^* = \sqrt{(1-m)/m}$.*

2.6. Illustration

The effect of economic integration on the equilibrium distribution of firms n and on the footlooseness of firms as expressed by $|\epsilon_{\text{reloc}}|$ is illustrated in figure 3. In the left panel, country H is larger ($m > 1/2$) and has higher production costs ($c > 1$), compared to country F. The size advantage of H is sufficiently large such that $m > c^2/(1+c^2)$, and (starting from $\phi = 0$), H attracts a larger share of firms (bold line) when trade costs decline. Given the production

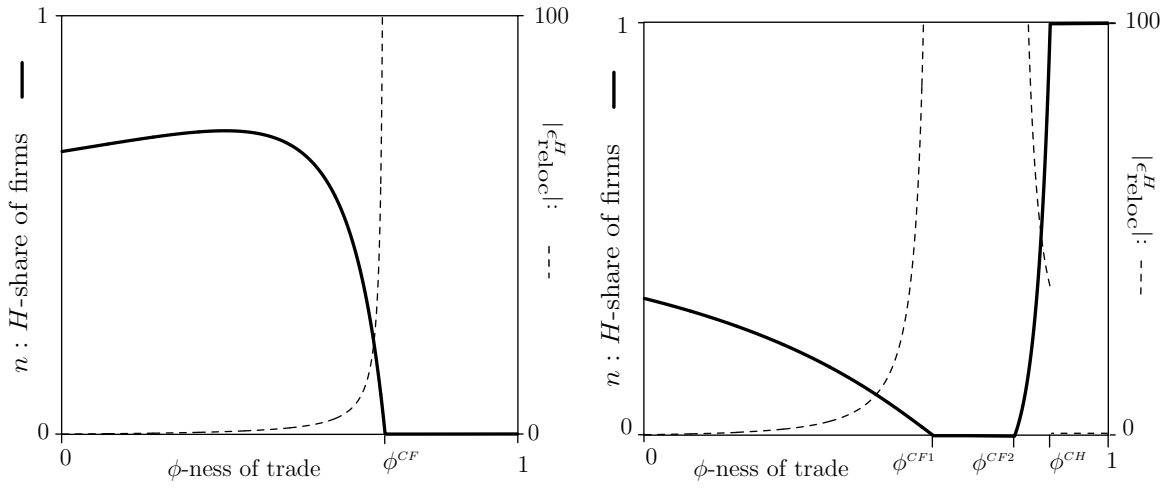

Figure 3: The share of manufacturing firms in country H (solid line, left scale) and the sensitivity of this share to changes in productions costs $|\epsilon^H_{\text{reloc}}|$ (dotted line, right scale), both as a function of trade freeness. The left panel shows the case of a large production cost handicap and moderate size advantage in country H ($c = 1.18$ and $m = 2/3$). The right panel shows the case of a size disadvantage and a moderate production cost advantage in country H ($c = 0.94$ and $m = 1/3$).

cost disadvantage of country H, all firms eventually relocate in country F if trade becomes sufficiently free beyond ϕ^{CF}. The market size advantage of H is not sufficiently large, for the existence an intermediate interval of trade freeness for which H can attract all manufacturing firms[7]. The elasticity of firm relocation $|\epsilon^H_{\text{reloc}}|$ (dashed line) is monotonically increasing in ϕ as long as both countries contain some firms. When ϕ approaches ϕ^{CF}, the level of trade freeness where all firms leave H, the sensitivity $\frac{\partial n}{\partial w_H}$ is expressed with respect to an ever decreasing remaining share of firms n and $|\epsilon^H_{\text{reloc}}|$ becomes infinitely large. For $\phi > \phi^{CF}$, ϵ_{reloc} is undefined as there are no manufacturing firms in H. In the right panel, H is relatively small ($m < 1/2$), but has a production cost advantage ($c < 1$). The market size disadvantage of H is sufficiently large compared to its production cost disadvantage for H to loose all manufacturing firms to F in the intermediate interval of trade costs $[\phi^{CF1}, \phi^{CF2}]$. In the right panel, the elasticity of firm relocation $|\epsilon^H_{\text{reloc}}|$ (dashed line) first becomes infinitely large as ϕ approaches ϕ^{CF1} and all firms locate in F. When ϕ continues to increase and surpasses the level ϕ^{CF2}, firms start relocating back to H and $|\epsilon^F_{\text{reloc}}|$ declines. This will take place until all firms have relocated to H at the point ϕ^{CH}. For $\phi \geq \phi^{CH}$, $|\epsilon^H_{\text{reloc}}|$ is *locally* zero: the firms in H do not relocate in response to *small* changes in H's wages if there exist agglomeration rents from locating in H.

[7] An intermediate interval of trade-freeness where H is able to attract despite its cost handicap exists if and only if $c < 1/(2\sqrt{(1-m)m})$, or equivalently, $m - 1/2 > \frac{\sqrt{c^2-1}}{2c}$.

3. Sector level union wage demands when firms are internationally mobile

So far we focused on the international distribution of firms, taking wages in both countries as given. In this section the manufacturing wage in country F is assumed to be competitive, and determined in the homogeneous good sector A of country F, such that $w_F = w_F^A = \alpha_F^A$ (see equation (2)). The manufacturing wage in country H, in contrast, is set by a monopoly union which operates at the sectoral level. When determining the optimal wage demand, this union takes into account the aspects of firm behaviour established in the previous section. When both countries contain firms, the union rationally anticipates that not all firms relocate for a small wage increase as tighter competition abroad and softer domestic competition tend to equalise profits in both countries before all firms relocated. In the case of full agglomeration, however, the existence of agglomeration rents in a country allows wages to be increased up to the point where profits are equalised between countries, without causing any relocation at all. The union will exploit this property to appropriate all agglomeration rents in the form of higher wages.

If agglomeration forces are sufficiently strong $\sigma > 2$, the union may respond to small changes in its environment by discontinuously lowering its wage demands and cause a sudden shift from an interior solution where both countries contain firms, to a corner solution where the unionised country contains all firms (or vice versa). Whether such discontinuous change occurs, or -more generally- whether a corner solution or an interior solution will be chosen by the union has to be determined numerically. Nevertheless a lot of intuition can be gained obout the conditions which make either case more likely by studying the underlying model.

In spite of this ambiguity, the the optimal union wage demand and its properties can be derived both for interior equilibria and for corner solutions. It is shown that (1) local union wage demands are not always increasing in the foreign wage level, (2) union wages are a non-monotonic function of trade freeness if there exist asymmetries between countries and trade is sufficiently free, (3) freer trade or a smaller home-market do not necessarily make countries more sensitive to the foreign wage level.

3.1. The optimal union wage demand

Assume that a monopoly union acting on the level of the manufacturing sector seeks to maximise

$$U = nl(w_H - w_H^A) = n(\sigma - 1)\frac{\alpha_H}{w_H}(w_H - w_H^A), \tag{12}$$

where $l = (\sigma - 1)\frac{\alpha_H}{w_H}$ is the equilibrium firm-level labour demand. Equation (12) is a simple but standard specification for union utility which has been widely used throughout the literature (see for example Oswald, 1985; Layard, Nickell, and Jackman, 2005), apart from the fact that

we let aggregate labour demand nl depend on the number of firms n in the country. This number of firms in turn depends on the market size, local and foreign wages, local and foreign productivity levels, and trade costs, as described in section 2. Union utility U equals the product of aggregate employment nl and the difference between the manufacturing wage w_H and the competitive A-sector wage $w_H^A = \alpha_H^A$ (see equation (2)), which serves as a benchmark against which union wages are gauged. It it assumed that the sector in which the union operates is sufficiently small compared to the overall economy, such that the union ignores the effect of its wage demands on the economy-wide price level. The union does take into account how wages affect manufacturing prices and thus the location choice of firms within its sector. This seems a reasonable assumption for the case of sector-level bargaining which is dominant in Europe[8].

Union utility equals 0 at both endpoints of the interval $[w_H^A, w_H^{CF}]$, is strictly positive for all w_H in $]w_H^A, w_H^{CF}[$ and therefore *necessarily* reaches a maximum in this interval.[9] The shape of U as a function of w_H will determine whether the union sets wages at an intermediate level where both countries contain firms (an interior equilibrium) or at the corner solution where wages are set such that country H attracts all firms.

For interior equilibria, the optimal union wage demand w_H^* is a solution of $\partial U / \partial w_H = 0$. This first order condition can be written as

$$\boxed{w_H^* = w_H^A + w_H^A \frac{1}{|\epsilon_{\text{reloc}}(w_H^*, w_F, \phi)|} \qquad \text{if } 0 < n < 1.} \tag{13}$$

where ϵ_{reloc} is given by

$$\epsilon_{\text{reloc}}(w_H, w_F, \phi) \equiv \frac{\partial n}{\partial w_H} \frac{w_H}{n} = (1-\sigma) \frac{m(1-\phi^2)(1-c^2) + (c-\phi)^2}{(c-\phi)(1-c\phi)(c^{CF}-c)} < 0.$$

and in turn c is defined as $c \equiv \left(\frac{w_H}{\alpha_H} \Big/ \frac{w_F}{\alpha_F} \right)^{\sigma-1}$.

If some parameter change causes all firms to leave the country, $|\epsilon_{\text{reloc}}|$ becomes infinitely large, and the union wage converges towards the outside option wage $w_H^A = \alpha_H^A$. Given this

[8] For example the union IG metal in Germany is likely to take into consideration the effects of its actions on the international competitiveness of the sector and aggregate labour demand. But even the actions of such a large union would have only a relatively small effect on the overall German consumer price index which also contains prices of non-manufacturing goods and imports. In a realistic context with multiple manufacturing sectors with separate unions (which is not explicitly considered in this paper), the consumer price index would also contain prices of manufacturing goods from these other sectors; prices which are not directly affected by the actions of the individual sector level union under consideration.

[9] The uninteresting case $w_H^A > w_H^{CF}$ is excluded as it would imply that all firms prefer to locate in country F, even with manufacturing wages in H lowered to the A-sector level w_H^A.

property it is convenient to define the union wage in H for $n = 0$ as $w_H^* = w_H^A$, although for $n = 0$ country H does not contain any manufacturing firms and the union wage therefore is rather immaterial.

For the case of full agglomeration in H, unions set wages marginally below the level which keeps firms indifferent between locations, such that $w_H = w_H^{CH}$, or

$$\boxed{w_H^* = w_H^{CH} = \frac{\alpha_H w_F}{\alpha_F}(c^{CH})^{\frac{1}{\sigma-1}} \qquad \text{if } n = 1.} \tag{14}$$

Here $w_F = \alpha_F^A$ is the wage which a manufacturing firm would pay in country F. The optimal union wage demand for full agglomeration implies that firms earn zero agglomeration rents[10]: the unionised manufacturing workers appropriate all the agglomeration rents which firms would have earned in the absence of unions in the form of higher wages.

3.1.1. Interior or corner solution?

Given the fact that union wages enter the model non-linearly through $c = \left(\frac{w_H \alpha_F}{\alpha_H w_F}\right)^{\sigma-1}$, it is impossible to write conditions containing only model parameters determining whether an internal or a corner solution will be chosen by the union. Nevertheless, a lot of intuition can be gained about the factors which make it more likely for either of these cases to occur by carefully considering the determinants of the shape of U as a function of w_H. Although the occurrence of an interior equilibrium or a corner solution has to be determined numerically (it can be determined analytically for some specific cases), the comparative static properties for both corner and interior solutions can always be derived analytically and are interesting in their own respect. These properties will be discussed in the next section.

To gain some insight into whether an interior solution or a corner solution will be chosen, realise that the shape of $U(w_H)$ ultimately depends on how n and $(w_H - w_H^A)/w_H$ change with w_H, since $U = \xi n(w_H - w_H^A)/w_H$ with ξ some constant. Three cases[11] can be distinguished depending on the level of w_H^A relative to w_H^{CH} and the shape of n. These different cases are illustrated in figure 4. The first case occurs when the wage w_H^{CH} at which all firms locate in country H is small such that $w_H^{CH} < w_H^A$. In this case any union wage demand between w_H^A and w_H^{CF} implies that both countries contain firms. The second case occurs when w_H^{CH} is large relative to w_H^A, and the share of firms in the country n decreases fast when wages are increased

[10] As $c = c^{CH}$ when $w_H = w_H^{CH}$, the agglomeration rents as defined in equation (11) are given by $z_H = r_H/r_F = c^{CH}/c = 1$ when wages are set according to equation (14).

[11] Recall that the uninteresting case $w_H^A > w_H^{CF}$ is not considered as it would imply that all firms prefer to locate in country F, even with manufacturing wages in H lowered to the A-sector level w_H^A.

(ϵ_{reloc} is high). In this case U is decreasing over the interval $]w_H^{CH}, w_H^{CF}[$ and the union will set the wage at w_H^{CH} such that country H contains all firms. In the third intermediate case where w_H^{CH} is not much larger than w_H^A, the chosen wage depends on the exact shape of n over the interval $]w_H^{CH}, w_H^{CF}[$ and whether the union chooses a wage which attracts all firms or chooses an interior solution will have to be determined numerically. We now discuss each of these cases more in detail.

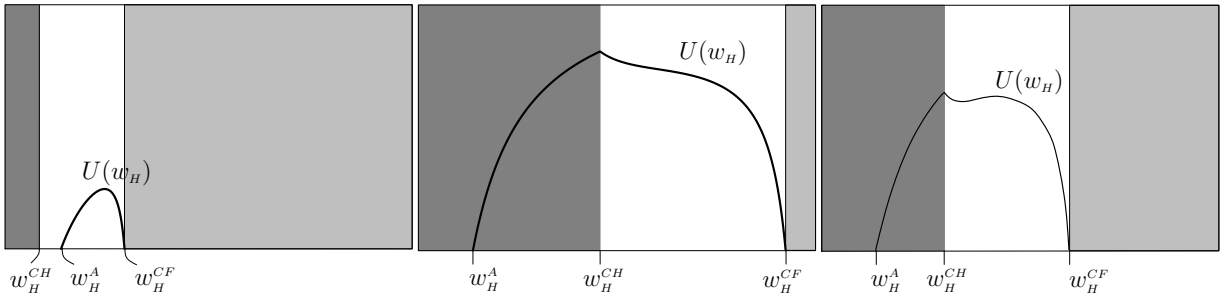

Figure 4: If $w_H^{CH} < w_H^A$, the optimal union wage implies an interior equilibrium (left panel). If w_H^{CH} is sufficiently large compared to w_H^A, U is downward sloping over the interval $]w_H^{CH}, w_H^{CF}[$ and the union sets wages at w_H^{CH}, attracting all firms (middle panel). If w_H^{CH} is only moderately higher than w_H^A the level of U at the unique interior maximum of U has to be compared numerically with the level of U at the corner solution w_H^{CH} (right panel).

Case 1 If $w_H^{CH} < w_H^A$, both countries will contain firms for any w_H in $]w_H^A, w_H^{CF}[$ and the optimal union wage demand always implies an interior equilibrium $0 < n < 1$. Union wages therefore are set according to equation (13). This case is illustrated in the left panel of figure 4. As ϵ_{reloc} contains w_H with non-integer exponents through $c = \left(\alpha_F w_H / \alpha_H w_F\right)^{\sigma-1}$ the union wage can not generally be written as an explicit function of the model parameters for interior equilibria. Despite this fact, the exact comparative static properties of the union wage demand can and will be derived analytically using the implicit function theorem in the next sections.

Case 2 If $w_H^A < w_H^{CH}$, the shape of U over the interval $]w_H^{CH}, w_H^{CF}[$ determines whether utility reaches a maximum at w_H^{CH} (a corner solution) or in $]w_H^{CH}, w_H^{CF}[$ (interior solution). If the slope of U in $]w_H^{CH}, w_H^{CF}[$ is negative if for all w_H in $]w_H^{CH}, w_F^{CF}[$, the union will set wages such that the corner solution holds and all firms agglomerate in country H. The slope of U over the interval $]w_H^{CH}, w_H^{CF}[$ is given by

$$\frac{w_H - w_H^A}{w_H} > \frac{1}{-\epsilon_{l,w} - \epsilon_{\text{reloc}}} = \frac{1}{1 - \epsilon_{\text{reloc}}}, \tag{15}$$

where the definition of ϵ_{reloc} is given in equation (10). Unfortunately this condition cannot be written in terms of model parameters alone. Condition (15) will hold under two conditions. Firstly, w_H^A should be sufficiently small relative to w_H^{CH}, such that $(w_H - w_H^A)/w_H$ is high and does not increase fast as a function of w_H. With $(w_H - w_H^A)/w_H$ close to one, the slope of U is mainly

determined by n. Secondly, it must be the case that -compared to the increase in $(w_H - w_H^A)/w_H$- the mass of firms $n(w_H)$ decreases sufficiently fast such that $-\epsilon_{\text{reloc}}$ is high (this is the case, for example, if trade costs are low).

If condition (15) holds, union utility is decreasing over $[w_H^{CH}, w_H^{CF}]$ and this is a sufficient condition for the union to choose a corner solution, where country H attracts all firms. The union wage demand then is given by equation (14). This case is illustrated in the middle panel of figure 4.

Case 3 If $w_H^A < w_H^{CH}$ and condition (15) does not hold then U is increasing over a section of $[w_H^{CH}, w_H^{CF}]$ and reaches a maximum in $[w_H^{CH}, w_H^{CF}]$. The interior maximum will be local, however, if two conditions hold (1) w_H^{CH} is not much larger than w_H^A, such that the term $(w_H - w_H^A)/w_H$ in union utility increases sufficiently fast beyond w_H^{CH}, and (2), simultaneously, n first decreases fast beyond w_H^{CH} (such that U in total decreases immediately beyond w_H^{CH}) but then n becomes less steep, such that the increase in $(w_H - w_H^A)/w_H$ again dominates the shape of U. If $\sigma \leq 2$ then n does not exhibit this behaviour and $U(w_H)$ will be concave. The union will then always pick the interior equilibrium if condition (15) does not hold. As $\partial U / \partial w_H = 0$ can not generally be solved for w_H, the utility level at different points in the interval $[w_H^{CH}, w_H^{CF}]$ where $\partial U / \partial w_H = 0$ and the utility level at the corner solution w_H^{CH} must be compared numerically when $\sigma > 2$.

Summarising the discussion on the prevalence of corner solutions versus interior solutions with union wage setting, it holds that for low values of w_H^{CH} relative to w_H^A, the union optimally sets wages such that both countries contain firms, according to equation (13). If $w_H^{CH} < w_H^A$ this is always the case. If, in contrast, w_H^{CH} is sufficiently high relative to w_H^A the optimal union wages equals w_H^{CH} (equation (14)). The union wage is set at the highest level which is compatible with all firms locating in country H. For intermediate levels of w_H^A and w_H^{CH}, union utility at the interior equilibrium and the corner solution must be compared numerically if $\sigma > 2$.

The fact that the utility function is not necessarily concave over the interval $[w_H^A, w_H^{CF}]$ when $\sigma > 2$ makes it possible that small parameter changes cause a discontinuous response in the optimal union wage demand, and hence in the international distribution of firms. More specifically, a small parameter change may induce the union to switch between a corner solution where the unionised country attracts all firms and a solution where both countries contain some manufacturing firms. This discontinuity is interesting given the fact that the model does not exhibit such a 'catastrophic agglomeration' property without the presence of unions. The lower panel of figure 5 illustrates how a small change in the foreign wage level (horizontal axis) can induce a discontinuous change in the optimal union wage demand.[12] If foreign wages

[12]The parameter values of the graph are $w_H^A = w_F^A = 1$, $\phi = 0.1, \sigma = 8, m = 2/3$.

exceed some critical level, the union prefers to lower wages to the point where it attracts all firms. Although interesting, the properties of discontinuous changes will not be further investigated in this paper.

The comparative static properties of the optimal union wage for small parameter changes can be determined analytically both in the case of an interior solution and a corner solution, with the caveat that the utility at the interior and corner solution should always be compared numerically to verify that a discontinuous regime shift did not occur. The remainder of this paper derives the comparative static properties of the optimal union wage demand for interior and corner solutions separately.

3.2. Foreign wage changes and union wage demands

If union wages are set such that the country is able to attract all firms, union wages move in line with the agglomeration rents. The agglomeration rents in a country are defined as the ratio of profits in this country to the (potential) foreign profits. As is clear from equation (14) a foreign wage increase makes the foreign country less attractive, increasing the home country's agglomeration rents, and leading to higher union wage demands.

Proposition 5. *Under full agglomeration, an increase (decrease) in the foreign manufacturing wage leads to a local union wage increase (decrease).*

The effect of a foreign wage change for interior solutions is derived in appendix A.1. Consider first the effect of a small deviation of w_F around the symmetric case $c = 1,\ m = 1/2$

$$\left.\frac{\partial w_H^*}{\partial w_F}\right|_{c=1,m=\frac{1}{2}} = -\left.\frac{\partial^2 U}{\partial w_H \partial w_F}\middle/\frac{\partial^2 U}{\partial w_H{}^2}\right|_{c=1,m=\frac{1}{2}} = \frac{2\phi(\sigma-1)}{(1-\phi)^2+4\phi(\sigma-1)} > 0. \tag{16}$$

As might be expected, a small increase in the foreign wage around the symmetric case implies higher local union wage demands.

In the general asymmetric case an interesting relationship between local and foreign wages emerges: the union wage w_H^* may reach a maximum as a function of foreign wages w_F at some point $w_F^\dagger$. This is the point where firm location is the least sensitive to wage changes (see equation (13)), such that $w_F^\dagger$ coincides with the minimum of the elasticity of firm relocation expressed as a function of foreign wages $\epsilon_{\text{reloc}}(w_F)$. Further foreign wage increases then lead to lower union wage demands in the remaining firms. Such a minimum of $\epsilon_{\text{reloc}}(w_F)$ exists under the quite weak necessary and sufficient condition $m < (1-2\phi^2)/(1-\phi^4)$. A proof is given in appendix A.1 for the case $\sigma = 2$ and in a technical appendix which is available from the author

on request for the general case $\sigma > 1$. If this condition is not met, then w_H^* is always increasing in w_F.[13] The following proposition therefore holds:

Proposition 6. *For symmetric countries, a small increase in the foreign wage always leads to an increase of the local union wage demands. For asymmetric cases with interior solutions this does not hold: under the weak conditions $\phi < 1/\sqrt{2}$ and $m < (1-2\phi^2)/(1-\phi^4)$ there exists a level of w_F above which increases in the foreign wage imply lower union wage demands.*

The upper left panel of figure 5 shows how the share of firms located in H, n (solid line), changes as a function of the foreign wage level for the general asymmetric case. The dotted line shows the sensitivity of firm relocation to changes in w_H expressed as the elasticity $|\epsilon^H_{\text{reloc}}|$.[14] The right panel shows the corresponding union wage demand. In the left panel we see that the share of firms n is more sensitive to wage changes at extreme levels, close to w_F^{CF} or w_F^{CH}. This is a direct consequence of the balance between agglomeration and dispersion forces which determines the firm location behaviour in the economic geography model, as was already illustrated in figure 1. At moderate levels of w_F, the market crowding effect is large and changes in foreign or local wages do not greatly affect the international distribution of firms (the n-curve is relatively flat, the elasticity of relocation is low). This is the reason why the union makes the highest wage demands at these intermediate levels of foreign wages, as can be seen in the right panel of figure 5.

Discussion. It might be surprising that a foreign wage increase may lead to a lower local union wage demand. This property makes sense, however, as in our model union wages are rationally set as a function of the *marginal* effect of wages on the international distribution of firms as expressed by $|\epsilon_{\text{reloc}}|$. A decrease in the level of foreign wages always leads to a decrease in the local number of firms and runs counter to union interests. The decreasing foreign wage may simultaneously imply a decrease in the marginal effect of further wage changes on the distribution of firms, however, which leads to higher optimal union wage demands in the remaining firms.

Note that when foreign wages w_F are lowered to the level w_F^{CF} (where c approaches c^{CF}) and all firms start leaving H, the elasticity of relocation $|\epsilon^H_{\text{reloc}}|$ in H approaches infinity (see equation (10)). The union wage demand then converges to the outside-option A-sector wage

[13] Only if trade costs are very low or the country is quite large compared to the freeness of trade, local union wage demands are always increasing with higher foreign wages. For empirically relevant values such as $\phi = 0.2$ the stated conditions imply that the market share m of country H must exceed 0.92 for $\partial w_H^* / \partial w_F > 0$ to hold for all levels of w_F which give rise to an internal equilibrium.

[14] $|\epsilon^H_{\text{reloc}}|$ is also directly related to the slope of n in function of w_F, as $\frac{\partial n}{\partial w_F}\frac{w_F}{n} = -\frac{\partial n}{\partial w_H}\frac{w_H}{n} = -\epsilon_{\text{reloc}} = |\epsilon^H_{\text{reloc}}|$.

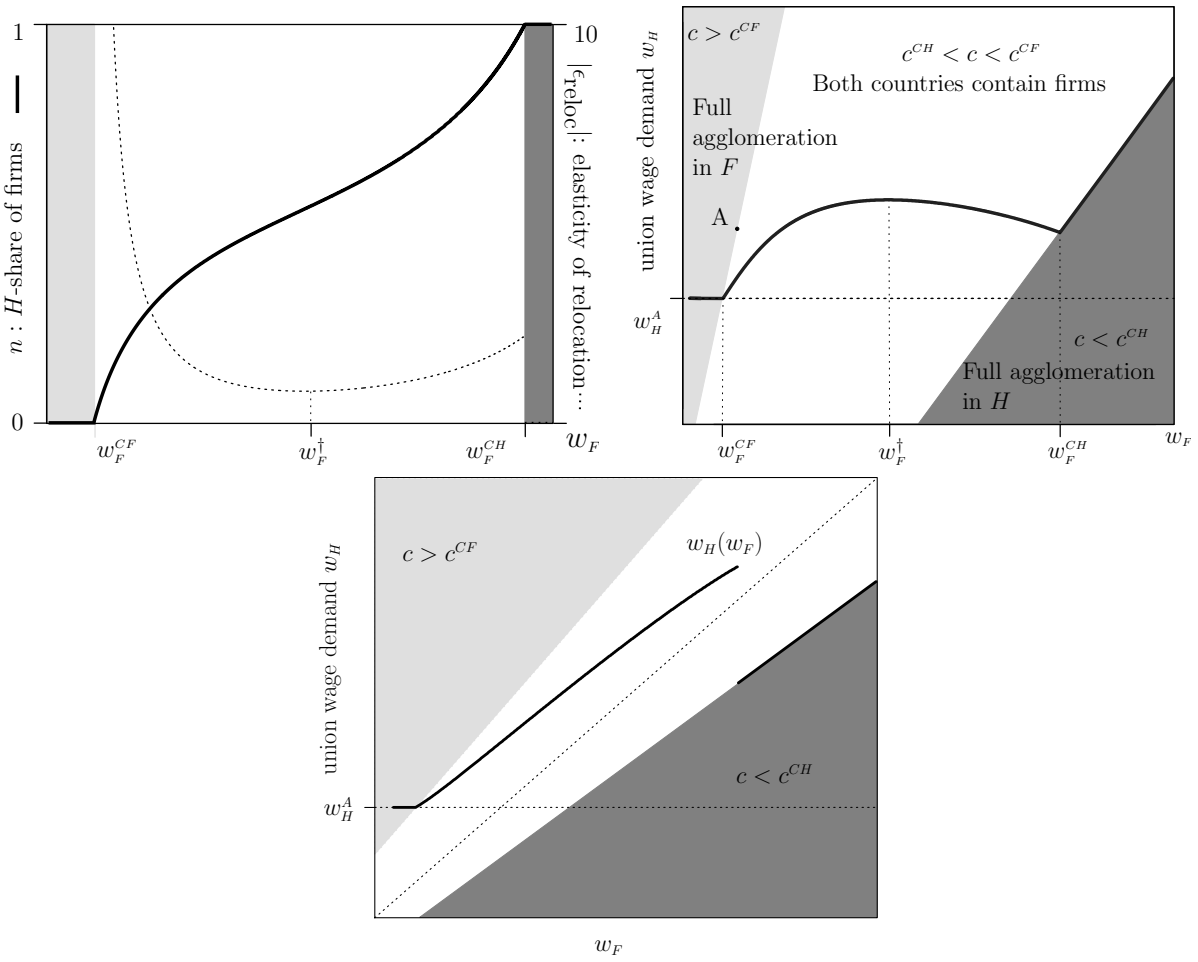

Figure 5: The international distribution of firms and the relocation elasticity (upper left panel) and the union wage demand (upper right panel), as a function of the foreign wage w_F. The lower panel illustrates the discontinuous effect of a small foreign wage change may have if $w_H^A < w_H^{CH}$ and $\sigma > 2$.

$w_H^A = \alpha_H^A$. Given our assumption that unions fully take into account the mobility of firms, it is intuitive that unions are willing to make ever larger wage concessions in such a situation, in an attempt to retain some employment and obtain positive utility.

Models with fixed union wage demands or wage bargaining outcomes (for example Picard and Toulemonde, 2006) or models where wages are proportional to firm profits (for example Head and Mayer, 2006) do not share the property that union wages are steadily lowered and converge to the level of the outside-option wage w_H^A as firms are leaving the country, although firms are equally assumed to be perfectly mobile in these models.[15] The reason is that, in these models, unions take firm location as given when setting wages. This may lead to situations,

[15]For the case of firm level bargaining, which is more popular in the literature, the combined assumption of costless firm relocation and international profit equalisation in interior equilibria should give each firm a perfect

however, where no firm is willing to locate in a country at the union wage demand derived in these models (resulting in 0 utility for the local union), whereas lowering wages to some level between the reservation wage w_H^A and the fixed union wage could attract a positive number of firms (resulting in positive utility for the union). Point A in the upper right panel of figure 5 is an example of such a point where a union which takes into account the possibility of firm relocation would want to lower its wage demands.

Assuming that unions take the location of firms as given might be reasonable if unions are wholly unable to commit to a wage contract, and firm investments are location specific and sunk. It seems unlikely, however, that the established sector-level unions which are prevalent in Europe are unable to commit to wages at all. As argued in the introduction, even with large sunk and localised investments, at least some firms in a sector are likely to be at the end of an investment-cycle at any point in time, and the fact that these firms may relocate in response to higher wage demands should be taken into account by a rational sector-level union. Moreover, if firms are sufficiently patient, they may abandon their local investments and relocate even if this is non-profitable in the short-term, in order to punish opportunistic unions. This would force even extremely short-minded unions to take into account that firm relocation is a real possibility (see Espinosa and Rhee, 1989; Addison and Chilton, 1998). Governments also seem to serve as an intermediate which enables unions to make credible commitments. In several European countries maximum sector-level union wage increases are included in central agreements. In Belgium and Italy, these agreements even refer explicitly to the evolution of foreign wages.

3.3. The effect of freer trade

A decrease in trade costs has an ambiguous effect on union wage demands.

Consider first the case of full agglomeration, where the union wage moves in line with the agglomeration rents. Following proposition follows directly from the properties of agglomeration rents as described in section 2.5.

Proposition 7. *If the larger country attracts all firms, union wages are a hump-shaped function of trade freeness with a top at $\phi = \sqrt{(1-m)/m}$. If the smaller (low-cost) country attracts all firms, union wages are strictly increasing with trade freeness.*

outside option (relocation) during firm-union wage negotiations. If the union fully takes this into account, union wage demands should equal the alternative wage, except in the case of full agglomeration where international profit differences may persist. In this case the gap between firm profits and the outside option (potential foreign profits) constitutes an agglomeration rent over which the firm and union may bargain.

But even when both countries contain firms, increasing freeness of trade may imply higher union wage demands in a small country with a comparative advantage in manufacturing, provided trade is sufficiently free. Consider the case where country F is sufficiently large to attract the industrial core for some intermediate levels of trade freeness[16], even when union wages in H are lowered to the level of the local alternative wage $w_H^A = \alpha_H^A$. If country H has a comparative advantage in manufacturing, however, such that $\frac{\alpha_H^A}{\alpha_H}$ is lower than the foreign relative production costs $\frac{w_F}{\alpha_F} = \frac{\alpha_F^A}{\alpha_F}$, there necessarily exists a level of trade freeness $\phi < 1$ above which unions in H will again be able to set a wage which is both above w_H^A and below the level w_H^{CF} at which all firms locate in F. Summarising, we have that:

Proposition 8. *For interior solutions, increasing trade freeness leads to lower union wages except when (1) the country is small ($m < 1/2$), (2) it has a comparative advantage in manufacturing ($\frac{\alpha_H^A}{\alpha_H} < \frac{\alpha_F^A}{\alpha_F}$), and (3) trade is sufficiently free such that $\phi > 2m$. In that case union wages may increase with freer trade even if both countries contain firms (proof see appendix A.2).*

Figure 6 illustrates the effect of ϕ on union wages. The left panel shows the case where country H has a production cost disadvantage ($c > 1$) but is significantly larger (m>1/2) such that it attracts all firms for values of ϕ between ϕ^{CH1} and ϕ^{CH2}. In this case, starting at $\phi = 0$, union wages are initially monotonically decreasing as trade becomes freer and both countries contain firms. For levels of ϕ between ϕ^{CH1} and ϕ^{CH2} all firms locate in H, however, and union wages are a bell-shaped function of ϕ in this interval as the union appropriates the hump-shaped agglomeration rents. For low trade costs, the market size advantage matters less, and firms start relocating back to the low-cost country F while union wage demands continue to fall between ϕ^{CH2} and ϕ^{CF}. Beyond ϕ^{CF}, trade costs are so low H cannot attract any manufacturing firms even with wage demands lowered up to the level w_H^A, and all manufacturing firms locate in F. The right panel of figure 6 shows the opposite case, which was also depicted in the right panel of figure 3, where H is small ($m < 1/2$) but has a comparative advantage in manufacturing. If H is sufficiently small, union wages will decline with increasing freeness of trade up to the point where all firms leave the country despite the fact that union wages are lowered to the level of the outside-option wage w_H^A, at the point ϕ^{CF1}. For ϕ exceeding ϕ^{CF2}, however, the importance of market-access has become sufficiently small relative to the importance of production costs in the location decision of firms, and H is again able to attract

[16] An interval where F is able to attract all firms exists if $\left(\frac{\alpha_H^A w_F}{\alpha_H \alpha_F^A}\right)^{\sigma-1} = \left(\frac{\alpha_H^A \alpha_F}{\alpha_H \alpha_F^A}\right)^{\sigma-1} > 2\sqrt{m(1-m)}$, since the union in H will only be willing to lower wages up to the point $w_H^* = w_H^A = \alpha_H^A$ if it can not attract firms with wage demands in excess of $w_H^A = \alpha_H^A$.

firms for union wages in excess of w_H^A. Union wage demands subsequently increase for the interior equilibria between ϕ^{CF2} and ϕ^{CH} where firms relocate back towards H (the exception described in proposition 8) and continue to increase with full agglomeration in H beyond ϕ^{CH}, as the union appropriates the increasing agglomeration rents in H (see proposition 7).

If trade is perfectly free ($\phi = 1$), country H will only be able to attract the industrial core if it has a comparative advantage in manufacturing, such that $\frac{\alpha_H^A}{\alpha_H} < \frac{\alpha_F^A}{\alpha_F}$. This is the case for country H at the right edge of the right panel of figure 6. At $\phi = 1$, the critical values of for agglomeration in H and F coincide ($c^{CH} = c^{CF} = 1$): for perfectly free trade, the market size asymmetry becomes irrelevant to firms, and only international differences in production costs determine where firms locate. Including the case where firms are just indifferent between locations, the condition for full agglomeration in H is $c \leq 1$, or, given the definition $c = \left(\frac{w_H \alpha_F}{w_F \alpha_H}\right)^{\sigma-1}$,

$$\frac{w_H}{\alpha_H} \leq \frac{w_F}{\alpha_F}$$

or, since $w_F = w_F^A$,

$$\frac{w_H}{\alpha_H} \leq \frac{\alpha_F^A}{\alpha_F}.$$

With full agglomeration, the optimal union wage demand w_H^* is set according to equation (14), and since this implies that unions make the highest possible wage demand which is compatible with full agglomeration in H we have

$$\frac{\alpha_H^A}{\alpha_H} < \frac{w_H^*}{\alpha_H} = \frac{\alpha_F^A}{\alpha_F}.$$

If and only if country H has a comparative advantage in manufacturing such that $\frac{\alpha_H^A}{\alpha_H} < \frac{\alpha_F^A}{\alpha_F}$, there will exist an optimal union wage demand w_H^* at $\phi = 1$, which both exceeds the alternative wage $w_H^A = \alpha_H^A$ and is marginally below the level w_H^{CH} at which countries are indifferent between locations. Moreover, for perfectly free trade, the size of the comparative advantage fully describes by how much unions are able to set wages in excess of the competitive wage level $w_H^A = \alpha_H^A$.

Discussion. The result that decreasing trade costs may lead to higher union wage demands is not unique to our model. In the two-country Cournot duopoly setting of Naylor (1999), for example, labour demand increases with lower trade costs because the effect of additional access to the foreign market exceeds the negative impact of increased domestic competition,

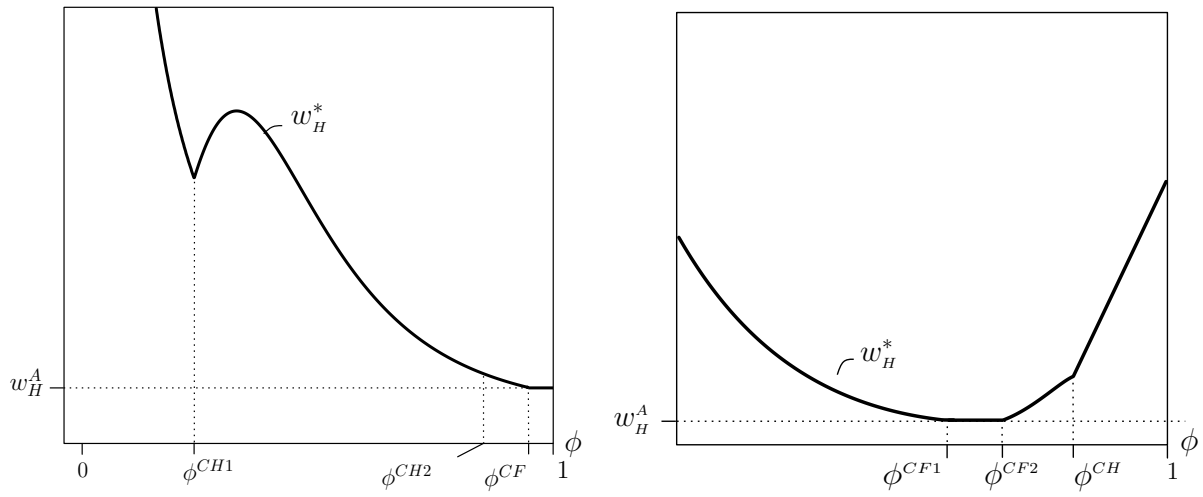

Figure 6: Union wage demands in the larger country (left panel) and the smaller country (right panel).

inducing unions to make higher wage demands. In our case, this property from the underlying forces in the economic geography model which drive the firm relocation behaviour.

The results for the effect of freer trade on wages under full agglomeration are derived directly from the properties of the agglomeration rents which are appropriated by the union. The attractiveness of the agglomerated country which is due to a market size advantage is a hump-shaped function of trade freeness. Freer trade will always increase the attractiveness of the country which is due to a production cost advantage. For perfectly free trade ($\phi = 1$) only the international production cost differential matters to firms and the union wage is only limited by the comparative advantage of the manufacturing sector in the agglomerated country.

For interior equilibria, the fact that increasing trade freeness may induce unions to increase wage demands in a sufficiently small country with a comparative advantage in manufacturing stems, firstly, from the fact that unions first rationally lower their wage demands to the absolute minimum w_H^A when all firms leave the country because the market size disadvantage becomes important for intermediate levels of trade freeness, and secondly, that when trade costs become very low and the market size differences become less important, the country with the lowest production costs will again be able to attract some firms. When this happens the elasticity of relocation in the smaller country declines, and unions in the smaller country will optimally make wage demands strictly exceeding w_H^A. The union wage demand then increases with freer trade.

Another interesting property of the model is the effect of freer trade on the sensitivity of local union wage demands to the foreign wage level. With ξ a vector of model parameters

apart from w_H, w_F and ϕ, it holds that

$$\frac{\partial w_H^*}{\partial w_F} = -\frac{\partial^2 U}{\partial w_H \partial w_F} \Big/ \frac{\partial^2 U}{\partial {w_H}^2} = T(w_H^*(w_F, \phi), w_F, \phi, \xi), \tag{17}$$

it holds that

$$\frac{\partial^2 w_H^*}{\partial w_F \partial \phi} = T_1 \frac{\partial w_H^*}{\partial \phi} + T_3, \tag{18}$$

where we write T_i to denote the partial derivative of T with respect to its i-th argument. Unfortunately, the expressions for the general asymmetric case are rather complex, but even for small deviations around the symmetric case $c = 1$ and $m = 1/2$ it can be shown that $\frac{\partial^2 w_H^*}{\partial w_F \partial \phi} < 0$. For $\sigma = 2$ the expression simplifies to $\frac{\partial^2 w_H}{\partial w_F \partial \phi} = -(1-\phi)/\left(\phi(1+\phi)\right)$.

When keeping the level of union wages fixed, freer trade does increase the slope of $w_H(w_F)$. This 'primary effect' of a change in ϕ on the slope $\partial w_H / \partial w_F$ corresponds to the term T_3 in equation (18), and is given by the partial derivative of equation (16) with respect to ϕ, for the symmetric case. To measure the full effect of ϕ, however, it has to be taken into account that changes in trade costs will also affect the level of union wage demands. Lower trade costs always lead to lower optimal union wage demands in the symmetric case. Lower union wages are less sensitive to foreign wages. The term $T_1 \frac{\partial w_H}{\partial \phi}$ reflects this 'secondary effect' and, as it turns out, it dominates the primary effect for the symmetric case, causing freer trade to decrease the sensitivity to foreign wages. For the more general asymmetric case this does not always hold. This effect also depends crucially on union preferences: in our case the union tends to increase wage demands to ever higher levels as the economy becomes more closed. Subsequently, trade liberalisation has a strong disciplinary effect and leads to lower union wage demands. As lower union wages are less sensitive to foreign wages, trade liberalisation makes union wages less sensitive to foreign wages after trade liberalisation. Should union preferences be given by $U = nl(w_H - w_H^A)^\gamma$, with $\gamma > 0$ the relative preference for wages compared to employment, and γ is sufficiently low, then union wage demands are less exorbitant in a more closed economy compared to the case where γ is higher. Union wages decrease more slowly after trade liberalisation, and union wages unambiguously become more sensitive to after trade liberalisation. .

3.4. Market size and union wage demands

A larger market size leads to higher union wage demands. For the case of full agglomeration, this follows directly from the properties of the agglomeration rents. With a larger home market, H's union can afford to set wages higher while keeping firms indifferent between locations.

For interior solutions the effect of market size on union wage demands also is unambiguously positive. For the symmetric case the effect is

$$\left.\frac{\partial w_H^*}{\partial m}\right|_{c=1,m=\frac{1}{2}} = \frac{2(1-\phi^2)}{(1-\phi)^2+4\phi(\sigma-1)} > 0.$$

Following the same approach as in appendices A.1 and A.2, it can be shown that the effect of market size on wages is positive in the general case with asymmetric countries. We therefore conclude

Proposition 9. *A larger home market size leads to higher union wage demands.*

A more surprising result is the ambiguous effect of market size on the sensitivity of the wage bargaining outcome with respect to the foreign wage level. Unfortunately, the expressions involved are rather complex and hard to sign for the general asymmetric case. But even for the symmetric case and $\sigma \geq 2$ it can be shown that, counter to intuition,

$$\left.\frac{\partial^2 w_H^*}{\partial w_F \partial m}\right|_{m=1/2,c=1} > 0.$$

For $\sigma = 2$ we have $\partial^2 w_H^* / \partial w_F \partial m \big|_{m=1/2,c=1} = 4(1-\phi)\phi/(1+\phi)^3$. Numerical analysis shows that for a large set of parameters an increase in a country's market size implies an increased sensitivity to foreign wages. The reason is that, as with the effect of freer trade, a higher market size always decreases the sensitivity to the foreign wage level *when keeping wage demands constant*, but a larger market size simultaneously leads to higher union wage demands which are more sensitive to foreign wage changes.

As can be seen in equation (14) a larger market always implies more sensitive wages in the case of full agglomeration.

This counter-intuitive result runs contrary to the findings of the literature on tax competition between asymmetric countries. For example the model of Gaigné and Riou (2007) predicts higher taxes and a lower sensitivity to the foreign tax level in larger countries. In models of tax competition which consider full agglomeration (see for example Baldwin and Krugman, 2004) higher foreign taxes lead to a higher local tax *level*. In most of these models, however, the market size does not affect how the optimal local tax depends on the foreign tax level. This is due to the fact that taxes are simply subtracted from firm profits whereas in our model wage changes alter firms' production costs.

3.5. The effect of unions on the distribution of firms

The focus of this paper was on how international firm mobility affects union wage demands. This section briefly considers the reverse question, on how union activity affects the equilibrium distribution of firms. This issue has received more attention in the literature, for example in the work of Picard and Toulemonde (2006). In their model, as in ours, all labour shed by the manufacturing sector due to union wage demands is fully absorbed by the CRS *A*-sector without affecting wages in that sector. Higher manufacturing wage demands therefore may increase aggregate nominal income. In the model of Picard and Toulemonde (2006) higher income implies more demand for manufacturing goods in a region and thus union activity increases the attractiveness of a country. Our model is quite different in that all income effects are absorbed by the demand for *A*-sector output. Higher wages in the manufacturing sector then do not alter demand for manufacturing goods in a country, causing wage increases to have an unambiguously negative effect on the profitability of firms and on the attractiveness of a location.

Consider the home market effect with unions setting wages in country H, with fixed foreign wages. With endogenous wages we have $n(m, w_{H}(m), \xi)$, where ξ groups the other parameters in the model which are fixed, and it holds that

$$\frac{\partial n}{\partial m} = n_1' + n_2' \frac{\partial w_{H}}{\partial m} \tag{19}$$

where we write n_i' for the partial derivative of $n(m, w_{H}(m), \xi)$ with respect to its i-th argument. As $\partial n / \partial w_{H} > 0$ (proposition 1) and $\partial w_{H} / \partial m < 0$ (proposition 9) union activity reduces the number of firms in the unionised country and attenuates the home market effect compared to the case with competitive labour markets.

4. Conclusion

This paper analysed the optimal wage demand of a monopoly union operating on the sector level, in face of internationally mobile firms. Using a simple two-country new economic geography model it was established how firms locate as a function of trade costs and international differences in market access, labour productivity and wages. Different from many contributions on union behaviour in an international context, unions are assumed to take firm mobility into account when making wage demands. It was shown that when both countries contain firms (interior equilibria) the union wage demand is inversely related to the responsiveness of firm location to wage changes. This responsiveness was referred to as the 'firm relocation elasticity'

throughout the paper.

When both countries contain firms, the firm relocation elasticity -and therefore the optimal union wage demand- changes non-monotonically as a function of foreign wages and trade costs.

At low levels of foreign wages, an increase in foreign wages leads to higher local union wage demands. Assuming some mild conditions hold, however, there exists a level of foreign wages above which further increases in foreign wages lead to lower union wage demands. Although a foreign wage increase benefits the union and increases the number of firms in a country, the marginal propensity of firms to relocate in function of union wage demands may simultaneously increase for these firms, leading to lower union wage demands.

Trade liberalisation generally increases the firm relocation elasticity, and therefore leads to lower union wage demands. Union wages may increase after trade liberalisation, however, if trade is sufficiently free, if the unionised country is sufficiently small, and if it has a comparative advantage in manufacturing. In this case, firms will relocate from the larger country to the more productive unionised country if trade costs become sufficiently low. This lowers the firm relocation elasticity and leads to higher union wage demands.

The non-monotonicity in the elasticity of firm relocation also creates the possibility of a discontinuous response by unions to small changes in the economic environment. If agglomeration forces are sufficiently strong ($\sigma > 2$), and various other conditions hold, a small increase in foreign wages, for example, may induce the union to substantially lower its wage demands and thereby cause a shift from a situation where both countries contain firms to the case where the unionised country attracts all firms.

When the country under consideration attracts all firms, the union sets wages as to keep firms indifferent between locations and appropriates all agglomeration rents in the form of higher wages. Agglomeration rents -and therefore union wage demands- are a hump-shaped function of trade freeness in the larger country, and are strictly increasing after trade liberalisation in the smaller country if it is able to attract all firms. For perfectly free trade, country size is irrelevant to the location decision of firms. All firms locate in the country with lower production costs. Unions then are able to extract the total comparative advantage in the country attracting the industrial core in the form of higher wages.

For small deviations around the symmetric case, lower trade costs or a smaller market size always lead to lower union wage demands, as might be expected. A counter-intuitive finding is that, even when considering small deviations around the symmetric case, the lower level of union wages in smaller and more open economies make that these are are less sensitive

to changes in the foreign wage level, compared to union wage demands in a larger or more closed economy.

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A. Appendices to chapter 1

A.1. The effect of foreign wages on union wage demands

In an interior equilibrium the optimal union wage demand w_H^* is the wage satisfying the first order condition

$$\frac{\partial U}{\partial w_H} = \frac{\partial n}{\partial w_H}\left[(w_H - w_H^A)l\right] + n\left[l + (w_H - w_H^A)\frac{\partial l}{\partial w_H}\right] = 0. \tag{20}$$

By the implicit function theorem the effect of a change in w_F on the wage bargaining outcome is given by

$$\frac{\partial w_H^*}{\partial w_F} = -\frac{\partial^2 U}{\partial w_H \partial w_F}\Bigg/\frac{\partial^2 U}{\partial {w_H}^2}.$$

The denominator is negative at points where U reaches a maximum (and we know that at least one such point must exist if U is increasing over a part of $[w_H^{CH}, w_H^{CF}]$, see condition 15), as it represents the second order condition for a maximum. The sign of $\frac{\partial w_H}{\partial w_F}$ therefore equals the sign of $\frac{\partial^2 U}{\partial w_H \partial w_F}$. Take the derivative of $\frac{\partial U}{\partial w_H}$ given in equation (20) and divide by $[(w_H - w_H^A)l]/w_H > 0$, which does not affect the sign. Substituting the first order condition $(w_H - w_H^A)/w_H^A = 1/|\epsilon_{\text{reloc}}| = -1/\left(\frac{\partial n}{\partial w_H}\frac{w_H}{n}\right)$ and using $\epsilon_{l,w} = \frac{\partial l}{\partial w}\frac{w}{l} = -1$ then gives

$$\text{sign}\left(\frac{\partial w_H^*}{\partial w_F}\right) = \text{sign}\left(\frac{\partial^2 n}{\partial w_H \partial w_F} w_H - \frac{\partial n}{\partial w_F}\frac{\partial n}{\partial w_H}\frac{w_H}{n}\right). \tag{21}$$

After dividing by n (which does not affect the sign) this equals

$$\text{sign}\left(\frac{\partial w_H^*}{\partial w_F}\right) = \text{sign}\left(\frac{\partial^2 n}{\partial w_H \partial w_F}\frac{w_H}{n} - \frac{\partial n}{\partial w_F}\frac{\partial n}{\partial w_H}\frac{w_H}{n^2}\right) = \text{sign}\left(\frac{\partial \epsilon_{\text{reloc}}}{\partial w_F}\right).$$

The reaction function therefore has a turning point at the level where $\frac{\partial \epsilon_{\text{reloc}}}{\partial w_F}$ switches sign, where ϵ_{reloc} reaches a minimum as a function of w_F as depicted in the left panel of figure 5. Although readily interpretable, the exact expression in function of the model parameters is rather complicated for the general asymmetric case and we omit it here.

When does such a turning point exist, where the union wage demand reaches a maximum as a function of foreign wages? Note that the derivative of the optimal union wage demand with respect to the foreign wage, evaluated at the lowest level of the foreign wage for which

the home country contains some firms, equals

$$\left.\frac{\partial w_H^*}{\partial w_F}\right|_{c=c^{CF}} = -\frac{\partial^2 U_H}{\partial w_H \partial w_F} \Bigg/ \left.\frac{\partial^2 U_H}{\partial w_H{}^2}\right|_{c=c^{CH}} = \frac{1}{2}\frac{w_H}{w_F}\,.$$

In other words: the sensitivity of the union wage with respect to the foreign wage expressed as the elasticity $\frac{\partial w_H}{\partial w_F}\frac{w_F}{w_H}$ equals $\frac{1}{2}$ when evaluated at w_F^{CF}. The slope of the reaction function at w_F^{CF} is always positive (as depicted in the right panel of figure 5).

Evaluated at the other extreme, w_F^{CH}, where the high foreign wage induces all firms to locate in H, and assuming $\sigma = 2$ to assure concavity of the objective function and thus the existence of a range of wages for which both countries contain firms, the slope of the reaction function for the case can be shown to equal

$$\begin{aligned}\left.\frac{\partial w_H^*}{\partial w_F}\right|_{c=c^{CH}} &= -\frac{\partial^2 U_H}{\partial w_H \partial w_F} \Bigg/ \left.\frac{\partial^2 U_H}{\partial w_H{}^2}\right|_{c=c^{CF}} \\ &= \frac{w_H}{w_F}\frac{-1+2\phi^2+m-\phi^4 m}{2\phi^2}.\end{aligned}$$

By solving the numerator for ϕ and m we conclude that the slope of the reaction function is negative at w_F^{CH} if $m < \frac{1-2\phi^2}{1-\phi^4}$. This is the case for common levels of ϕ and m. Under this conditions the reaction curve goes from positively sloped at w_F^{CF} to negatively sloped at w_F^{CH} and reaches a maximum between w_F^{CF} and w_F^{CH} at the point where $|\epsilon_{\text{reloc}}|$ as a function of w_F reaches a minimum. A technical appendix which is available from the author on request proves that this conditions is also necessary and sufficient for a maximum to be reached in the general case with $\sigma > 1$.

A.2. The effect of trade freeness on union wage demands

Proceeding as in appendix A.1 the effect of a change in ϕ on the union wage demand, $\partial w_H^* / \partial \phi$ has the same sign as

$$\frac{\partial^2 U}{\partial w_H \partial \phi} = \frac{\partial^2 n}{\partial w_H \partial \phi}\left[(w_H - w_H^A)l\right] + \frac{\partial n}{\partial \phi}\left[l + (w_H - w_H^A)\frac{\partial l}{\partial w_H}\right].$$

Dividing by $[(w_H - w_H^A)l]/w_H > 0$ does not affect the sign. Substituting the first order condition $(w_H - w_H^A)/w_H^A = 1/|\epsilon_{\text{reloc}}| = -1/\left(\frac{\partial n}{\partial w_H}\frac{w_H}{n}\right)$ and using $\epsilon_{l,w} = \frac{\partial l}{\partial w}\frac{w}{l} = -1$ then shows

$$\operatorname{sign}\left(\frac{\partial w_H}{\partial \phi}\right) = \operatorname{sign}\left(\frac{\partial^2 n}{\partial w_H \partial \phi} w_H - \frac{\partial n}{\partial \phi}\frac{\partial n}{\partial w_H}\frac{w_H}{n}\right). \tag{22}$$

This expression can be straightforwardly calculated from the long-run equilibrium definition of n from equation (7) yielding a complex expression we omit here. From the point of view of country H the expression (and therefore the effect of ϕ on w_H) can be shown to be negative unless it holds combined that $c < 1$, $m < 1/2$ and $\phi > 2m$ (the country under consideration has a cost advantage, is small, and trade is sufficiently free) in which case the effect of freer trade on the union wage demand can be positive. These are necessary but not sufficient conditions, however. The exact conditions under which $|\epsilon_{\text{reloc}}|$ decreases with freer trade (and union wage demands increase) hard difficult to derive.