

# WORKING PAPERS IN ECONOMICS

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No.09/10

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NORTH-SOUTH TECHNOLOGY  
TRANSFER IN UNIONISED  
MULTINATIONALS



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# North-South technology transfer in unionised multinationals

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November 23, 2010

## Abstract

We study how incentives for North-South technology transfers in multinational enterprises are affected by labour market institutions. If workers are collectively organised, incentives for technology transfers are partly governed by firms' desire to curb trade union power. This will affect not only the extent but also the type of technology transfer. While *skill upgrading* of southern workers benefits these workers at the expense of northern worker welfare, *quality upgrading* of products produced in the South may harm not only northern but also southern workers. A minimum wage policy to raise the wage levels of southern workers may spur technology transfer, possibly to the extent that the utility of northern workers decline. These conclusions are reached in a setting where a unionised multinational multiproduct firm produces two vertically differentiated products in northern and southern subsidiaries, respectively.

*Keywords:* North-South technology transfer; Multinationals; Trade unions; Minimum wages

*JEL classification codes:* F23; J51; O33

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# 1 Introduction

Is globalisation great news for less-skilled workers in developing and newly industrialized countries? Some fear for the consequences of globalisation for less qualified workers in the ‘northern’ developed part in the world. With increased trade openness, and with a more educated workforce in the North and an abundance of unskilled labour in the South, a simple comparative advantage story should imply that production which is not skill-intensive should move southwards, while more technologically advanced production is retained in the North. This could spell trouble for those in the North who find it difficult to acquire the necessary skills for such advanced production – they could either see their jobs disappear or their wage level dwindle to a very uncomfortable level.

However, the flip side of this coin should be that unskilled industries in the South expand, and that the demand for unskilled labour in these countries increases. While globalisation can lead to more wage inequality in the North, we should perhaps expect the reverse to happen in the South? Empirically, this does not seem to hold at all. A famous example is Mexico. Hanson and Harrison (1999) point out that Mexico experienced a dramatic increase in the skilled-unskilled wage gap during a period of trade liberalisation.<sup>1</sup> Esquivel and Rodriguez-Lopez (2003) and Verhoogen (2008) argue that the unexpected widening of wage differentials following trade liberalisation is rooted in technological change. More trade led to quality upgrading in Mexican production, benefitting the relatively more skilled workers in that economy. Zhu and Treffer (2005) develop a theoretical model with endowments-based comparative advantages and technological catch-up in the South. Southern catch-up causes production of the least skill-intensive northern goods to migrate to the South – where they become the most skill-intensive goods, and wage inequality increases both there and in the North. Their empirical analysis reveals that among developing and newly industrialised countries, the sharpest increase in inequality can be found where export shares have shifted towards more skill-intensive goods.

It is easy to grasp the idea that globalisation has lead to southern technological catch-up

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<sup>1</sup>See Goldberg and Pavcnik (2007) for a comprehensive review of empirical evidence showing similar results. Pavcnik (2003) studies technology transfer, skill upgrading and inequality in Chile. More recently, Rattsø and Stokke (2010) have drawn attention to the increasing wage inequality in South Africa following the fall of Apartheid and the subsequent increase in trade openness.

and a consequent sharp rise in wage inequality. An interesting follow-up question, though, is if there is something wrong from a welfare perspective about the way southern countries progress technologically? As unskilled labour is so excessively abundant, why should new technologies complement skills also in these countries? Acemoglu (1998) has argued that technical change is ‘directed’ in the sense that it complements or substitutes for other factors according to what pays. Acemoglu and Zilibotti (2001) adapt the theory of directed technological change to a North-South setting. In northern countries, technological development will naturally complement skills and contribute toward increased wage dispersion. If southern countries simply rely on catching-up technologically by copying technology developed in the North, also they will eventually implement these new technologies, even though they do not sit well with the composition of their labour forces. But this is not necessarily a market failure – copying a technology which does not perfectly fit one’s needs might be far better than having no technological development at all.

In the present paper we shed some light on these broader issues by focusing on the potential role played by different labour market institutions in determining the incentives for North-South technology transfer through multinational enterprises. It has long been recognised that multinationals play a ubiquitous role in technology transfers between the developed and the developing world. Caves (2007) cites many studies arguing that multinationals tend to install similar technologies in the South as the ones already being employed in the North, even though the relative factor abundance of different types of labour can be very different. Our paper develops a theoretical model where multinationals may determine how much and what type of knowledge that is transferred to subsidiaries in the South. A starting point assumption is that the workforce in the North is unionised. Will multinational corporations transfer technology to subsidiaries in the South as part of a power struggle with northern workforces? How will labour market institutions in the North and the South interact, and what does that in turn imply for technology transfer? In short, we are trying to find out what labour market institutions, such as the presence of trade unions and minimum wages both in northern and southern economies, imply for transfer of technology – and if this in turn can help explain why multinationals seem

to install rather advanced technologies even in countries where unskilled labour is available in abundance. This in turn could provide a part-answer to the question why globalisation and foreign direct investment seem to be accompanied with rising inequalities also in the South.

We look at two different forms of technology transfers. Firstly, a firm can upgrade the quality of the product produced in the South, making it more similar to what the multinational produces in the North. Secondly, the multinational can also transfer knowledge that upgrades the skills and productivity of southern labour. Unionised northern workers have no direct influence over what technologies their companies install in countries far away, but as we shall see, decisions on technology transfers may impact wage bargaining.<sup>2</sup> This influence on wage bargaining might in turn help decide how technology is transferred in a North-South framework. While we throughout assume that northern workers are unionised, our first assumption is that southern workers have no bargaining power, but there is a minimum wage policy that regulates wages in the formal sector in the South. In an extension to this benchmark model, we introduce trade unions also in the industrialising country, so that northern and southern unions within the same multinational in effect play a game against each other while putting forward wage claims. The effects of minimum wage policies in the South are then analysed also in the presence of unionised southern workers.

In the main version of the model, with unionised labour in the North and minimum wages in the South, stronger unions in the North lead to more technology transfers, both in the form of product quality upgrading and skill upgrading. Technology transfer clearly is a weapon that a multinational can use against its northern workforce. A higher southern wage level, on the other hand, will discourage incentives to upgrade product quality in the South, but incentives for skill upgrading can in fact be increased.<sup>3</sup> Thus, a minimum wage policy in the South will tend to shift incentives from product quality upgrading to skill upgrading. Interestingly, when technology choices are endogenous, it cannot be taken for granted that northern workers will benefit from higher wages in the South. On the contrary, northern workers might actually suffer

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<sup>2</sup>Dowrick and Spencer (1994) and Lommerud, Meland and Straume (2006) consider trade unions that can veto technological change, but in these models there are no southern trade unions or minimum wages, and new technology arrives exogenously.

<sup>3</sup>This is related to earlier results that minimum wages can encourage skill formation (Agell and Lommerud (1997) and Acemoglu and Pischke (1999)), although the context is very different.

if incentives for skill upgrading are stimulated to a sufficient extent.

In the extended version of the model, both northern and southern workers are represented by trade unions. These cannot coordinate their actions, so they are pitted against each other by the production decisions of the multinational. We find clearly that unions in the North and the South have opposite interests when it comes to skill upgrading. However, while northern workers lose from product quality upgrading, their southern counterparts will gain in some circumstances and lose in others. Since quality upgrading implies that competition between workers in the North and the South is intensified, this particular type of technology transfer might actually worsen the situation not only for northern workers, but also for their southern counterparts. Thus, although both types of technology transfers are generally profitable for the firm, technology transfer in the form of product quality upgrading might be a particularly effective instrument for multinationals in order to extract rents from workers. In this setting, with trade unions in both the North and the South, we also find that the introduction of a minimum wage (which may or may not bind in equilibrium) will generally stimulate incentives for technology transfer, and to a larger extent than in the main model without trade unions in the South.

Our paper clearly relates to the large literature on unionised international oligopoly.<sup>4</sup> The central question in that literature is how unionised workers in the North fare when they are exposed to harsher international competition. The labour market in the South is typically portrayed as competitive, and the fate of southern workers is not given attention. A partial exception is Grieben and Sener (2009), who use a North-South product cycle model, with unionised workers in the North, and study the effects on innovation by trade liberalisation both in the North and the South. Nevertheless, they also use the assumption that the labour market in the South is competitive.

As trade unions are not as prevalent in all northern economies as they are in some, several authors have sought to study labour market rigidities and globalisation in other frameworks than the unionised one. Firstly, there is a literature on spillover effects among countries from

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<sup>4</sup>See, e.g., Naylor (1998, 1999), Lommerud, Meland and Sørsgard (2003), Lommerud, Straume and Sørsgard (2006), Eckel and Egger (2009), Bastos and Kreickemeier (2009) and Ishida and Matsushima (2009).

national minimum wages.<sup>5</sup> Closer to the trade union literature are models of matching frictions, possibly with individual wage bargaining.<sup>6</sup> Finally, also models where workers have fair-wage preferences and this influences wage structures, should be mentioned.<sup>7</sup> Some of this work is tailored to a US-Europe context, with less emphasis on southern economies. But the most important difference between our paper and this whole body of literature is that we study wage formation within multinational firms. The interlinkages among workers in the same firm but in different countries then become pressing – and the question of within-firm technology transfer arises.

Another large body of literature relevant to our study concerns itself with North-South technology transfer within multinational corporations.<sup>8</sup> Even though this literature identifies many externalities in the technology transfer process, focus has not been on external effects on a unionised northern workforce, or on strategic interactions between trade unions representing workers in different subsidiaries of the multinational firm.

The remainder of this paper is organised as follows. The main model with wage bargaining in the North and an exogenous wage in the South is presented Section 2 and analysed in Sections 3-5. The model is then extended in Section 6 to capture the case where also workers in the South have collective bargaining power. Section 7 concludes the paper.

## 2 Model

Consider a firm that can produce a certain good in the North – denoted Brand  $N$  – using labour as the only factor of production with a linear technology, where one unit of labour produces one unit of output. Workers in the North are unionised and wages are decided in Nash bargaining between the firm and a trade union representing the workers. The firm has also the option to produce a lower-quality version of the good in the South – denoted Brand  $S$  – where the technology and skill-level are less advanced, but labour is cheap.

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<sup>5</sup>See, e.g., Davis (1998) and Egger, Egger and Markusen (2009).

<sup>6</sup>Examples of this literature include Davidson, Matusz and Shevchenko (2008), Helpman and Itskhoki (2010), Boughol (2010) and Decreuse and Maarek (2010).

<sup>7</sup>See, e.g., Agell and Lundborg (1995) and Egger and Kreickemeier (2009).

<sup>8</sup>See, e.g., Glass and Saggi (1998), Pack and Saggi (2001), Olsen and Osmundsen (2003), Cheng, Qiu and Tan (2005), Müller and Schnitzer (2006), and Blalock and Gertler (2008).

Product demand is derived from consumer preferences that correspond to a standard vertical differentiation framework (Mussa and Rosen, 1978). The firm can supply both brands to an integrated world market where consumers are heterogeneous with respect to their willingness-to-pay. More specifically, consumers are identified by a preference parameter  $\tau \sim U[0, a]$ , and the utility function of a consumer of type  $\tau$  is given by

$$u = \begin{cases} \tau - p_N & \text{if buying Brand } N \\ \mu\tau - p_S & \text{if buying Brand } S \end{cases}, \quad (1)$$

where  $p_i$  is the price of Brand  $i \in \{N, S\}$ , and Brand  $N$  is perceived to be of higher quality than Brand  $S$ . The quality difference is represented by  $1 - \mu$ , where  $\mu \in (0, 1)$ . We assume unit demand, where each consumer buys either one or zero units of one of the brands. The total consumer mass is normalised to 1.

Let  $q_i$  be the produced quantity of Brand  $i$ ,  $w_N$  the bargained wage in the North,  $w_S$  an exogenous wage level in the South and  $\phi \in (0, 1)$  a technology parameter measuring labour productivity in the South. If the firm produces both brands, and for a given technology level, profits are given by

$$\pi = (p_N - w_N)q_N + (p_S - \omega_S)q_S, \quad (2)$$

where  $\omega_S := \frac{w_S}{\phi}$  is the *effective wage* in the South.

The two parameters  $\phi$  and  $\mu$  represent the state of technology in the South. This state depends on the degree of technology transfer from the North to the South within the multinational firm. For a given initial state of technology ( $\phi_0$  and  $\mu_0$ ), the firm can increase both labour productivity and product quality by transferring technology ( $\Delta\phi$  and  $\Delta\mu$ , respectively) to the plant in the South. The cost of technology transfer is given by a function  $c(\Delta\phi, \Delta\mu)$ , which is (at least) twice differentiable, increasing, separable and strictly convex in both arguments, with  $c(0, 0) = 0$ . The state of technology in the South is thus given by  $\phi := \phi_0 + \Delta\phi$  and  $\mu := \mu_0 + \Delta\mu$ . We will refer to  $\Delta\phi$  and  $\Delta\mu$  as *skill upgrading* and *product quality upgrading*, respectively.



Workers in the North are represented by a trade union, whose utility is given by

$$U_N = (w_N - r_N)^\theta L_N, \quad (3)$$

where  $r_N$  is the reservation wage level,  $\theta > 0$  is a parameter measuring the degree of wage orientation, and  $L_N = q_N$  is the level of employment.

The sequence of events are assumed to be as follows:

Stage 0: The firm chooses its product line: Only Brand  $N$ , only Brand  $S$ , or both  $N$  and  $S$ .

Stage 1: Given that  $S$  will be produced, the firm chooses the degree of technology transfer – skill upgrading and product quality upgrading – from the North to the South.

Stage 2: The firm and its trade union bargain over the wage level in the North.

Stage 3: The firm chooses how much to produce.

Notice that, by placing the product line and technology transfer decisions prior to wage bargaining, we implicitly assume that it is impossible for the union to commit to a certain wage policy in order to influence these decisions directly.<sup>9</sup>

### 3 Optimal choice of product line

Assume that both brands are produced. From the utility function, demand is given by

$$q_N = \frac{a - \hat{\tau}}{a} \text{ and } q_S = \frac{\hat{\tau} - \frac{p_S}{\mu}}{a}, \quad (4)$$

where

$$\hat{\tau} := \frac{p_N - p_S}{1 - \mu}. \quad (5)$$

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<sup>9</sup>In the literature on trade unions and offshoring (Skaksen and Sørensen (2001), Zhao (2001), Lommerud, Meland and Straume (2009) and Koskela and Stenbacka (2009)), attention is implicitly focused on Stage 0, while ignoring what we here have dubbed Stage 1.

Thus, consumers with high willingness-to-pay ( $\tau > \hat{\tau}$ ) will buy Brand  $N$ , consumers with intermediate willingness-to-pay ( $\tau \in \left(\frac{p_S}{\mu}, \hat{\tau}\right)$ ) will buy Brand  $S$ , while consumers with low willingness-to-pay ( $\tau < \frac{p_S}{\mu}$ ) will refrain from buying.

The profit maximising prices are given by

$$p_N = \frac{1}{2}(a + w_N) \text{ and } p_S = \frac{1}{2}(a\mu + \omega_S). \quad (6)$$

The corresponding quantities are

$$q_N = \frac{a(1 - \mu) - w_N + \omega_S}{2a(1 - \mu)} \text{ and } q_S = \frac{\mu w_N - \omega_S}{2a(1 - \mu)\mu}. \quad (7)$$

The existence of an interior solution (i.e.,  $q_N > 0$  and  $q_S > 0$ ) requires that

$$w_N - a(1 - \mu) < \omega_S < \mu w_N. \quad (8)$$

**Proposition 1** *The following two conditions are necessary for the optimal product line to consist of both varieties:*

1. *The effective wage rate must be lower in the South than in the North*
2. *The quality difference between the two varieties must neither be too small nor too large.*

**Proof.** Follows immediately from (8). ■

If the first condition is violated, the firm will only produce Brand  $N$ , which by assumption can only be produced in the North. Notice that this condition implicitly rules out the possibility of producing both brands in the North (given that the production costs are equal for both brands). If the second condition is violated, the firm will either produce only Brand  $S$  in the South (if  $\mu$  is sufficiently large) or only Brand  $N$  (if  $\mu$  is sufficiently low).

In the following we will concentrate on the interior solution. To ensure that this solution exists for a parameter space that is as large as possible, we assume that  $\omega_S < r_N < a$ . By assuming that the effective wage rate in the South is lower than the reservation wage in the

North, we ensure that the first condition in Proposition 1 is always met. Then we know that interior solutions will always exist for intermediate ranges of  $\mu$ .

## 4 Wage bargaining

We assume that the wage level in the North is determined as a solution to the following Nash bargaining problem:

$$w_N = \arg \max (U_N - \bar{U}_N)^\alpha (\pi - \bar{\pi}_N)^{1-\alpha}, \quad (9)$$

where  $\alpha$  measures the relative bargaining strength of the trade union, and  $\bar{U}_N$  and  $\bar{\pi}_N$  are the disagreement payoffs of the union and the firm, respectively. We assume that the unionised workers do not have access to alternative employment during a bargaining conflict; i.e.,  $\bar{U}_N = 0$ . The firm, on the other hand, is still able to produce Brand  $S$  in the South during a conflict in the North. We assume that, in case of a bargaining conflict, the firm optimally adjusts its production of Brand  $S$  to maximise profits for  $q_N = 0$ . This implies that the disagreement payoff of the firm is given by

$$\bar{\pi}_N = \frac{1}{4} \frac{(a\mu - \omega_S)^2}{a\mu}. \quad (10)$$

The bargained wage is then given by

$$w_N = \frac{(2 - \alpha)r_N + \theta\alpha(\omega_S + a(1 - \mu))}{2 - \alpha(1 - \theta)}. \quad (11)$$

All comparative statics results for  $w_N$  are unambiguous, given that both brands are sold.

**Proposition 2** *The bargained wage in the North is*

1. *increasing in  $a$ ,  $\theta$ ,  $\alpha$  and  $r_N$ ;*
2. *decreasing in  $\phi$  and  $\mu$ ;*
3. *increasing in  $w_S$ .*

**Proof.** Follows immediately from (11). ■

The first part of the proposition is standard, and requires no further explanation. The second and third parts show how wages in the North depend on technology and labour market conditions in the South when production in the North and the South are linked through the firms production decisions. If labour productivity increases in the South (for instance through transfer of technology), the effective wage rate in the South will drop. This means that it becomes more profitable for the firm (partly) to replace production of Brand  $N$  with production of Brand  $S$ , which makes demand for labour in the North more elastic. In addition, a lower effective wage rate in the South increases the disagreement payoff of the firm in case of a bargaining conflict. Both these factors contribute to a lower bargained wage in the North. Similar effects apply to an increase in  $\mu$ . Transfer of technology that enables the firm to produce Brand  $S$  with a higher quality will reduce the bargained wage in the North. On the other hand, a higher effective wage rate in the South, for instance through an increase in the legal minimum wage, will then obviously be accompanied by an increase also in  $w_N$ .

For a given state of technology in the South, equilibrium quantities and prices for the two brands are given by

$$q_N = \frac{(2 - \alpha)(\omega_S + a(1 - \mu) - r_N)}{2(2 + \alpha(\theta - 1))(1 - \mu)}, \quad q_S = \frac{\alpha\theta(1 - \mu)(a\mu - \omega_S) + (2 - \alpha)(r_N\mu - \omega_S)}{2(2 + \alpha(\theta - 1))(1 - \mu)a\mu}, \quad (12)$$

$$p_N = \frac{(r_N + a)(2 - \alpha) + \alpha\theta(\omega_S + a(2 - \mu))}{2(2 + \alpha(\theta - 1))}, \quad p_S = \frac{\omega_S + a\mu}{2}. \quad (13)$$

Union utility and profits are

$$U = (\theta\alpha)^\theta \left( \frac{2 - \alpha}{2a(1 - \mu)} \right) \left( \frac{\omega_S + a(1 - \mu) - r_N}{(2 + \alpha(\theta - 1))} \right)^{\theta+1} \quad (14)$$

and

$$\begin{aligned} \pi = & \frac{(2 - \alpha)(\omega_S + a(1 - \mu) - r_N)((2 - \alpha)(a - r_N) - \theta\alpha(\omega_S - a\mu))}{4a(1 - \mu)(2 + \alpha(\theta - 1))^2} \\ & + \frac{(\theta\alpha(1 - \mu)(\omega_S - a\mu) + (2 - \alpha)(\omega_S - r_N\mu))(\omega_S - a\mu)}{4a\mu(1 - \mu)(2 + \alpha(\theta - 1))}. \end{aligned} \quad (15)$$

Based on (14) and (15), the union and the firm can be shown to have diametrically opposite incentives with respect to the state of technology in the South:

**Proposition 3** (i) *For a given state of technology, a higher wage in the South benefits the union in the North but reduces the profits of the firm.*

(ii) *A better state of technology in the South (higher  $\phi$  and/or  $\mu$  at zero cost) increases the profits of the firm but reduces union utility in the North.*

**Proof.** See the Appendix. ■

Notice that the positive relationship between labour conditions ( $w_S$ ) in South and union utility in the North is derived for a given state of technology in the South. If we endogenise the firm's technology transfer decision, improvement of labour conditions in the South might affect the incentives for technology transfer in a way that potentially harms the unionised workers in the North. This question will be dealt with in the next section.

## 5 Technology transfer

Prior to wage bargaining in the North, and assuming that the optimal product line involves producing both brands, the firm decides on the optimal degree of technology transfer (skill upgrading and product quality upgrading) to the plant in the South. For the parameter configurations that yield an interior solution for the optimal product line choice, we know from Proposition 3 (part (ii)) that  $\pi$  is monotonically increasing in  $\phi$  and  $\mu$ . Thus, a sufficiently convex cost function will secure an interior solution  $(\phi^*, \mu^*)$ , where technology is transferred from the initial level  $(\phi_0, \mu_0)$ .

Our main objective is to analyse how the incentives for North-South technology transfer depend on labour market conditions in the North and the South. More specifically, we want to examine how incentives for technology transfer depend on union bargaining power in the North ( $\alpha$ ) and the wage level in the South ( $w_S$ ).

We can assess the effect of marginal parameter changes around the interior solution,  $(\phi^*, \mu^*)$ ,

by evaluating the sign of the relevant second-order cross derivatives of the profit function.<sup>10</sup> Considering first the effect of union bargaining power in North on incentives for technology transfer, the sign of these effects are given by the signs of

$$\frac{\partial^2 \pi}{\partial \alpha \partial \phi} = \frac{2\theta(2-\alpha)(a(1-\mu) - (r_N - \omega_S))\omega_S}{(1-\mu)a(2+\alpha(\theta-1))^3\phi}, \quad (16)$$

$$\frac{\partial^2 \pi}{\partial \alpha \partial \mu} = \frac{(2-\alpha)\left(a^2(1-\mu)^2 - (r_N - \omega_S)^2\right)\theta}{a(1-\mu)^2(2+\alpha(\theta-1))^3}. \quad (17)$$

Similarly, the impact of a higher wage in the South – for example through minimum wage policies – is given by

$$\frac{\partial^2 \pi}{\partial \omega_S \partial \phi} = \frac{(2-\alpha)^2(r_N\mu - 2\omega_S) + \alpha\theta(1-\mu)(a\mu - 2\omega_S)(4-\alpha(2-\theta))}{2(1-\mu)(2+\alpha(\theta-1))^2\mu\phi^2a} \quad (18)$$

and

$$\frac{\partial^2 \pi}{\partial \omega_S \partial \mu} = - \left( \frac{(2-\alpha)^2(\omega_S + \mu(\mu r_N - 2\omega_S)) + \alpha\theta\omega_S(1-\mu)^2(4-\alpha(2-\theta))}{2a(2+\alpha(\theta-1))^2(1-\mu)^2\mu^2\phi} \right). \quad (19)$$

From (16)-(19), we can establish how incentives for technology transfer depends on labour conditions in the North (union strength) and the South (minimum wage), respectively, as follows:

**Proposition 4** (i) *Stronger trade unions in the North unambiguously increase incentives for both types of technology transfer.*

(ii) *A higher wage in the South always reduces incentives for product quality upgrading, while incentives for skill upgrading are increased (reduced) if*

$$\omega_S < (>) \hat{\omega} := \frac{\mu}{2} \left( \frac{a\alpha\theta(1-\mu)(4-\alpha(2-\theta)) + r_N(2-\alpha)^2}{\alpha\theta(1-\mu)(4-\alpha(2-\theta)) + (2-\alpha)^2} \right). \quad (20)$$

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<sup>10</sup>By the Implicit Function Theorem,

$$\frac{\partial \phi^*}{\partial \alpha} = - \frac{\frac{\partial^2 \pi}{\partial \alpha \partial \phi}}{\frac{\partial^2 \pi}{\partial \phi^2}} \quad \text{and} \quad \frac{\partial \mu^*}{\partial \alpha} = - \frac{\frac{\partial^2 \pi}{\partial \alpha \partial \mu}}{\frac{\partial^2 \pi}{\partial \mu^2}},$$

where  $\frac{\partial^2 \pi}{\partial \phi^2} < 0$  and  $\frac{\partial^2 \pi}{\partial \mu^2} < 0$ , due to the second-order conditions for the firm's profit-maximising choices of technology transfer.

**Proof.** See the Appendix. ■

The intuition for the first part of the proposition is quite straightforward. As stronger unions make the production of Brand  $N$  more expensive, the multinational firm can counteract this effect by transferring more technology to the South, which worsens the union's bargaining position in the North (cf. Proposition 2). Thus, through the particular product market linkage explored in this paper, we have identified a possible mechanism whereby the presence of powerful trade unions in the North will reinforce incentives for North-South technology transfer within multinational firms.

The second part of the proposition shows that labour conditions in the South have qualitatively different effects on the two types of technology transfer. In other words, a higher wage in the South might affect not only the extent but also the predominant *type* of technology transfer. While better labour conditions in the South always reduce incentives for product quality upgrading, incentives for skill upgrading are ambiguously affected. A higher wage in the South will increase the firm's incentives for technology transfers which improve labour productivity in the South, if the effective wage rate in the South is sufficiently low to begin with. A contributing factor to this result is the convexity of  $\pi$  in  $\omega_S$ . The higher the effective wage rate in the South, the lower is the positive profit gain of a marginal reduction in the effective wage rate through skill upgrading. Thus, as long as  $\omega_S < \hat{\omega}$ , a wage increase in the South will shift incentives for technology transfer from product quality upgrading to skill upgrading.

When seen in conjunction with Proposition 3, the second part of Proposition 4 suggests that, when endogenising the type and extent of technology transfer, the unionised workers in the North might not necessarily benefit from improved labour conditions in the South. The total effect of a higher wage in the South on union utility in the North is given, on general form, by

$$\frac{dU}{dw_S} = \frac{\partial U}{\partial w_S} + \frac{\partial U}{\partial \mu} \frac{\partial \mu^*}{\partial w_S} + \frac{\partial U}{\partial \phi} \frac{\partial \phi^*}{\partial w_S}. \quad (21)$$

The first term is the direct effect for a given state of technology, which is positive (cf. Proposition 3). The second term is the indirect effect via product quality upgrading. From Proposition 4 we know that this effect is also unambiguously positive. Thus, the dampening effect on incentives

for product quality upgrading reinforces the benefits that unionised workers in the North enjoy from better labour conditions in the South. However, the last term is negative if the effective wage rate in the South is sufficiently low. Thus, we cannot theoretically rule out the possibility that the overall effect of higher wages in the South might, paradoxically, be negative for the unionised workers, if this spurs skill upgrading in the South to a sufficient degree.

## 6 Wage bargaining in the South

In this section we endogenise  $w_S$  by assuming that also workers in the South are unionised. Along the lines of our previous analysis, we start out by characterising the labour market equilibrium and analysing how wages (in the North *and* the South) depend on technology. Subsequently, we investigate how minimum wage policies in the South affect incentives for technology transfer and, in turn, worker welfare in the North and the South.

We assume that workers in the South are organised in a trade union with utility

$$U_S = (w_S - r_S)L_S, \tag{22}$$

where  $L_S = q_S/\phi$  is the employment level in the South. To enhance tractability, we assume  $\theta = 1$  for unions in both the South and the North, and additionally, we set the reservation wage level in the North equal to unity ( $r_N = 1$ ) and assume  $r_S < 1 < a$ , which will ensure that wages are lower in the South than in the North. Additionally, we set  $\alpha = \frac{1}{2}$ .

### 6.1 Equilibrium wages

Wages in the North and the South are now both determined in multi-unit bargaining between the multinational firm and the two trade unions. We assume initially that there are no minimum wage policies in place. Applying the multi-unit bargaining model developed by Davidson (1988), the bargained wages in the North and the South are given by the simultaneous solution to the



following pair of Nash bargaining problems:

$$w_N = \arg \max (U_N - \bar{U}_N) (\pi - \bar{\pi}_N), \quad (23)$$

$$w_S = \arg \max (U_S - \bar{U}_S) (\pi - \bar{\pi}_S), \quad (24)$$

where  $\bar{\pi}_N$  and  $\bar{\pi}_S$  are the profits of the firm in case of a bargaining conflict between the firm and the union in, respectively, the South and the North. As before, we assume  $\bar{U}_i = 0$ ,  $i = S, N$ , and that the firm optimally adjusts its production of the other brand to maximise profits during a bargaining conflict with one of the unions.  $\bar{\pi}_N$  is still given by (10), while

$$\bar{\pi}_S = \frac{(a - w_N)^2}{4a}. \quad (25)$$

Simultaneously solving the two maximisation problems, the bargained wages are

$$w_N = \frac{4a(1 - \mu) + 12 + 3\rho_S}{16 - \mu}, \quad (26)$$

$$w_S = \frac{\phi(a\mu(1 - \mu) + 12\rho_S + 3\mu)}{16 - \mu}, \quad (27)$$

where  $\rho_S := \frac{r_S}{\phi}$  is the ‘effective reservation wage’ in the South. For consistency, we need eq. (8) to be fulfilled. This requires

$$\underline{\rho} < \rho_S < \bar{\rho}, \quad (28)$$

where

$$\underline{\rho} := \frac{1}{3}(4 - \mu - 4a(1 - \mu)) \quad (29)$$

and

$$\bar{\rho} := \frac{\mu(a(1 - \mu) + 3)}{4 - \mu}. \quad (30)$$

Notice that  $\bar{\rho} > \underline{\rho}$ , implying the existence of an interior solution, if  $a > 1$ . Furthermore, the above conditions satisfy  $w_N > w_S$ , making the North the high-cost country. From (26)-(27), we derive:

**Proposition 5** (i) *The bargained wage in the North is increasing in  $a$  and  $r_S$ , and decreasing in  $\phi$  and  $\mu$ ;*

(ii) *The bargained wage in the South is increasing in  $a$ ,  $r_S$  and  $\phi$ , and decreasing in  $\mu$  iff  $a > \frac{48+12\rho_S}{32\mu-\mu^2-16}$  and  $\mu > 16 - 4\sqrt{15}$ .*

**Proof.** See the Appendix. ■

The first part of the proposition shows that the comparative statics properties of the wage in the North are qualitatively unchanged by endogenising the wage in the South (cf. Proposition 2). However, the important thing to notice here is the asymmetric impact of technology investment on the wages in the South and the North. An increase in  $\phi$  enables the firm to produce Brand  $S$  cheaper, since the effective wage rate in the South drops. When workers in the South are unionised, they are able to capture some of this gain through wage bargaining, implying a higher wage in the South. The drop in the effective wage rate in the South has two direct effects that contribute to a drop in the bargained wage in the North. First, the firm's incentive to produce more of the cheaper Brand  $S$  and less of the more expensive Brand  $N$  makes labour demand more elastic in the North. Second, the disagreement payoff of the firm in case of a bargaining conflict in the North increases.<sup>11</sup>

Regarding product quality upgrading, the effects are somewhat different. An increase in  $\mu$  implies that some demand is shifted from Brand  $N$  to Brand  $S$ . All else equal, this contributes to a lower wage in the North and a higher wage in the South. However, an increase in  $\mu$  also increases the implicit competition between workers in the North and the South, since the two brands become more equal.<sup>12</sup> The increased intensity of competition between the two unions has a dampening effect on wages. This reinforces the wage drop in the North while it makes the direction of the wage response in the South ambiguous. If  $\mu$  is sufficiently high to begin with ( $\mu > 0.51$ ) and  $a$  is also sufficiently high, the inter-union competition effect is the dominant force for wage negotiations in the South, leading to a drop in  $w_S$ .

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<sup>11</sup>Since workers in the North and the South are implicitly Bertrand competitors, there are also second-order feedback effects.

<sup>12</sup>This can be seen from (5), where a given price difference yields a larger change in quantity when  $\mu$  is higher.

For a given state of technology in the South, union utility and profits are

$$U_N = \frac{3(3\rho_S - (4 - \mu - 4a(1 - \mu)))^2}{2(16 - \mu)^2 a(1 - \mu)}, \quad (31)$$

$$U_S = \frac{3(3\mu + a\mu(1 - \mu) - (4 - \mu)\rho_S)^2}{2(16 - \mu)^2 a(1 - \mu)\mu}, \quad (32)$$

$$\pi = \frac{9 \left[ \begin{array}{c} 2\rho_S\mu(8a\mu - 8a - \mu - 8) - \rho_S^2(7\mu - 16) \\ -\mu(7\mu - 16 + 2a(\mu + 16)(1 - \mu) - a^2(9\mu + 16)(1 - \mu)) \end{array} \right]}{4(16 - \mu)^2(1 - \mu)a}. \quad (33)$$

Based on these union utility and profit expressions, we derive the following results:

**Proposition 6** (i) *An increase in  $\phi$  leads to higher profits and union utility in the South, but reduces union utility in the North.*

(ii) *An increase in  $\mu$  leads to higher profits and lower union utility in the North, while union utility in the South is reduced iff  $\mu > \frac{16}{31}$  and  $a > \frac{\mu(48+3\mu-6\mu^2)-\rho_S(-64+124\mu-17\mu^2+2\mu^3)}{\mu(31\mu-16)(1-\mu)}$ .*

**Proof.** See the Appendix. ■

As before, the firm benefits from both types of transfers, absent any cost of investment. Similarly, the negative impact of both types of technology transfer for workers in the North comes as no surprise – given Proposition 5. This is also in line with the results for the case of an exogenous wage in the South (cf. Proposition 3). However, workers in the South benefit from skill upgrading, but might not benefit from product quality upgrading. This is in line with the wage effects discussed above (Proposition 5). Thus, with wage bargaining in the North and the South, it might be the case that a particular type of technology transfer – product quality upgrading – makes workers in *both* countries worse off. As previously discussed in relation to Proposition 5, the reason is that, for certain parameter configurations, product quality upgrading can be used as an effective instrument to increase the degree of competition between the two unions, causing wages to fall in both countries.

## 6.2 Technology transfer and minimum wage policies

In line with the previous analysis, we now ask how labour market conditions in the South affect the incentives for technology transfer. More specifically, we consider the effect of a minimum wage policy on the optimal transfer of technology. We will distinguish between the cases where (i) the minimum wage binds (i.e., the minimum wage is set above the equilibrium wage level resulting from bargaining), and (ii) the minimum wage does not bind but affects wage bargaining through an increase in the reservation wage level.

### 6.2.1 A binding minimum wage

Except for the case where wages in the South decrease as a response to product quality upgrading (see Proposition 5), the minimum wage cannot be set at the present wage level, but must be assumed to be somewhat higher, for the policy to have an effect on technology transfer. However, below we analyse the case where the minimum wage is set exactly at the equilibrium level given by (27), but wages are nevertheless treated as constant under the minimum wage. If incentives for technology transfer strictly increase in this case, we can conclude that the minimum wage can be somewhat above the equilibrium level without affecting this result.

In the following, we use our previous results and calculate the difference in  $\frac{\partial \pi}{\partial (*)}$  with and without minimum wages. For consistency, we set  $\theta = r_N = 1$  and  $\alpha = \frac{1}{2}$ . We have

$$\begin{aligned} \Delta_\phi &= \left( \frac{\partial \pi}{\partial \phi} \Big|_{w_S = \text{const}} - \frac{\partial \pi}{\partial \phi} \Big|_{w_S = \text{variable}} \right) \Big|_{w_S = w_S^*} \\ &= \frac{3(8a\mu(1-\mu) + 8\mu + \mu^2 - (16 - 7\mu)\rho_S)(a(1-\mu) + 3)}{8\phi(16 - \mu)^2(1-\mu)a}, \end{aligned} \quad (34)$$

where  $w_S^*$  is given by (27). Equivalently, the effect of a binding minimum wage on incentives for product quality upgrading is given by

$$\begin{aligned} \Delta_\mu &= \left( \frac{\partial \pi}{\partial \mu} \Big|_{w_S = \text{const}} - \frac{\partial \pi}{\partial \mu} \Big|_{w_S = \text{variable}} \right) \Big|_{w_S = w_S^*} \\ &= \frac{3(\mu(8 + \mu + 8a(1-\mu)) - (16 - 7\mu)\rho_S)(12\rho_S + 48 + a(16 - 32\mu + \mu^2))}{8(\mu a(1-\mu)(16 - \mu)^3)}. \end{aligned} \quad (35)$$

We obtain the following results:

**Proposition 7** (i) *The introduction of a binding, small impact, minimum wage will increase incentives for skill upgrading.*

(ii) *The incentives for product quality upgrading is reduced when introducing a binding minimum wage of any size if  $a > \frac{12\rho_S+48}{32\mu-\mu^2-16}$  and  $\mu > 4(4 - \sqrt{15})$ .*

**Proof.** See the Appendix. ■

In order to grasp the intuition behind these results, consider first the incentives for skill upgrading. From Proposition 4 we know that an exogenous increase in  $w_S$  will increase (decrease) incentives for skill upgrading if  $\omega_S < (>)\hat{\omega}$ . This suggests that the introduction of a binding minimum wage might reduce incentives for skill upgrading if the wage level is sufficiently high to begin with. However, Proposition 7 shows that this will not happen for ‘small impact’ minimum wages. The reason is that, in the absence of a binding minimum wage, incentives for skill upgrading are lower with than without wage bargaining in the South. When workers in the South are unionised, part of the gain from the technology transfer will be appropriated by workers in the South through higher wages (cf. Proposition 5). This wage effect of the technology investment is eliminated by a binding minimum wage, increasing the firm’s return on a given technology transfer. The elimination of the wage response means that incentives for skill upgrading is unambiguously increased by the introduction of a binding (but relatively small impact) minimum wage. Similarly, if the bargained wage is increasing in  $\mu$ , the introduction of a binding minimum wage makes the firm able to upgrade product quality without the fear of a corresponding wage increase in the South. Consequently, incentives for such investments will be higher than if wages were exogenous to begin with.

When seen in conjunction with Proposition 4, we can conclude that the effect of minimum wages on technology transfer is clearly different when the possibility of wage bargaining in the South is introduced. In short, the introduction of a binding minimum wage in the South is more likely to spur technology transfer – of both types – when workers in the South have some bargaining power in the absence of such a minimum wage. With wage bargaining, a small impact minimum wage will now always increase incentives for skill upgrading, regardless of the original

wage level. Furthermore, product quality upgrading now only becomes less profitable if both  $a$  and  $\mu$  are sufficiently high, which roughly corresponds to the case where the bargained wage in South is decreasing in  $\mu$  (cf. Proposition 5). What is similar to the previous case, though, is that a minimum wage policy in the South may lead to a shift in incentives for technology transfer from product quality upgrading to skill upgrading, but not the other way around.

Another interesting implication of Proposition 7 is that the presence of collective bargaining power for workers in the South increases the likelihood that workers in the North might suffer from the introduction of a binding minimum wage in the South. The direct effect is still positive ( $\partial U_N / \partial w_S > 0$ ), but this could in principle be outweighed by increased technology transfer of both types.

### 6.2.2 A non-binding minimum wage

Since the reservation wage of workers should reflect outside options, it is reasonable to assume that it should be (partly) affected by a legal minimum wage that also applies to the labour market outside the firm in question. Thus, one possible effect of a minimum wage policy is that the minimum wage does not bind directly, but indirectly affects the bargained wage through an increase in the reservation wage  $r_S$ . How would this affect incentives for technology transfer? As in Section 5, we can investigate this question by simply looking at the second order partial derivatives of the profit function.

The signs of the effect on skill upgrading and product quality upgrading incentives are given by the signs of, respectively,

$$\frac{\partial^2 \pi}{\partial \phi \partial r_S} = \frac{9(8\mu(a(1-\mu) + 1 + \mu) - (32 - 14\mu)\varpi_S)}{2\phi^2(16 - \mu)^2(1 - \mu)\mu a} \quad (36)$$

and

$$\frac{\partial^2 \pi}{\partial \mu \partial r_S} = \frac{9\left(2\rho(560\mu - 190\mu^2 + 21\mu^3 - 256) - 2\mu^2(16a(1 - \mu)^2 + 160 - \mu(23 + 2\mu))\right)}{4\phi(16 - \mu)^3(1 - \mu)^2\mu^2 a}. \quad (37)$$

From (36)-(37), we derive the following results:

**Proposition 8** (i) If  $r_S$  increases, the incentives for skill upgrading are always increased if  $a > \frac{64-38\mu+\mu^2}{6(1-\mu)}$ , always decreased if  $a < \frac{128-112\mu+11\mu^2}{32(4-5\mu+\mu^2)}$  and otherwise increased (decreased) if  $\rho_S < (>) \frac{8\mu a(1-\mu)+8\mu+\mu^2}{32-14\mu}$ .

(ii) If  $r_S$  increases, the incentives for product quality upgrading are decreased unless  $a > \frac{48-14\mu+2\mu^2}{30\mu-5\mu^2-16}$  and  $\rho_S > \frac{\mu^2(16a(1-\mu)^2+160-\mu(23+2\mu))}{560\mu-190\mu^2+21\mu^3-256}$ .

**Proof.** See the Appendix. ■

In one particular sense, the above proposition reinforces the results in Proposition 7. By assuming workers in the South to have some bargaining power, the scope for minimum wage legislation to stimulate both types of technology transfer is enlarged, even if the minimum wage is not binding but only works indirectly through a higher reservation wage. However, the parameter space where incentives for product quality upgrading are strengthened is comparatively narrow, since  $a > 4$  and  $\mu > 3 - \frac{\sqrt{145}}{5} \approx 0.59$  are necessary, but not sufficient, conditions for a positive relationship between  $r_S$  and the firm's optimal choice of  $\mu$ .

## 7 Concluding remarks

How do labour market conditions affect North-South technology transfer in multinational firms? In contrast to previous literature, we focus on internal labour market externalities caused by the power struggle between trade unions representing workers in different subsidiaries (in the North and the South) of the multinational firm. In this context, North-South technology transfer – whether skill upgrading or product quality upgrading in the South – is partly motivated by the multinational firm's desire to curb trade union power. It is therefore no surprise that northern workers stand to suffer from such transfer of technology. A more striking finding is that a particular type of technology transfer, namely product quality upgrading, may hurt not only northern but also southern workers. This possibility arises if workers have collective bargaining power not only in the North, but also in the South.

A minimum wage policy that lifts the wage level of the poorer southern workers may affect worker welfare in unexpected ways through changes in technology transfer incentives. We find that higher wages in the South can actually increase incentives for skill upgrading and may even

hurt northern workers as an end result, if the incentives for skill upgrading are triggered to a sufficient degree. We also find that a minimum wage policy is more likely to induce technology transfer, even in the form of product quality upgrading, if southern workers have collective bargaining power.

Does our analysis suggest that technology transfer is excessive? One should perhaps refrain from bold policy statements. We have identified one externality at play stemming from multinationals' desire to gain power over northern (and sometimes even southern) workers. However, in a fuller picture there might be many other externalities and market imperfections at play, so in the end technology use in a developing country might be too small.<sup>13</sup> Nevertheless, in a well-known study Xu (2000) points out that US multinationals seem to be sources of technological spillovers only in countries who already have achieved some level of development. The least developed countries fail to take advantage of such transfers and spillovers because they lack the minimum human capital threshold level that is necessary in order to do this. In such a light, we think it is somewhat paradoxical that power struggle in the North can lead multinationals not only to produce in the South at a very high technological level, but that technology transfers could take the form of producing products in the South that almost can match product quality in the North, rather than investing in upgrading the skills of the host country labour force. However, our analysis also shows that a potential remedy for directing investments away from product quality upgrading and towards skill upgrading is a minimum wage policy that lifts the wage level of workers in developing countries.

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<sup>13</sup>For example, Ghatak and Jiang (2002) point to credit market imperfections as a reason for a too large informal sector in the developing world.



## Appendix

**Proof of Proposition 3.** (i) The positive sign of  $\frac{\partial U_N}{\partial w_S}$  follows immediately from (14). From (15) we have

$$\frac{\partial \pi}{\partial w_S} = - \frac{(2-\alpha)^2 (\mu r_N - \omega_S) + \theta \alpha (1-\mu) (4-2\alpha + \theta \alpha) (a\mu - \omega_S)}{2a\mu\phi (1-\mu) (2+\alpha(\theta-1))^2}. \quad (\text{A1})$$

This expression is monotonically decreasing in  $r_N$ . From (12),  $q_S > 0$  and  $q_N > 0$  require that  $r_N \in (\underline{r}, \bar{r})$ , where  $\underline{r} := \frac{\omega_S(2-\alpha) - \theta\alpha(a\mu - \omega_S)(1-\mu)}{\mu(2-\alpha)}$  and  $\bar{r} := \omega_S + a(1-\mu)$ . Since  $\bar{r} - \underline{r} = \frac{(\theta\alpha - \alpha + 2)(a\mu - \omega_S)(1-\mu)}{(2-\alpha)\mu}$ , this set is non-empty iff  $a\mu > \omega_S$ . Thus, the existence of an interior solution requires that  $a\mu > \omega_S$ . From (A1), we have that  $\left. \frac{\partial \pi}{\partial w_S} \right|_{r_N = \underline{r}} = - \frac{\theta\alpha(a\mu - \omega_S)}{2a\mu\phi(2-\alpha+\theta\alpha)} < 0$  if  $a\mu > \omega_S$ . Since  $\frac{\partial \pi}{\partial w_S}$  is monotonically decreasing in  $r_N$ , we conclude that  $\frac{\partial \pi}{\partial w_S} < 0$  for all  $r_N \in (\underline{r}, \bar{r})$ .

(ii) From (14) we have

$$\frac{\partial U_N}{\partial \mu} = - \left( \frac{\theta\alpha(\omega_S + a(1-\mu) - r_N)}{2+\alpha(\theta-1)} \right)^\theta \frac{(2-\alpha)(\theta a(1-\mu) + r_N - \omega_S)}{2a(1-\mu)^2(2+\alpha(\theta-1))} < 0 \quad (\text{A2})$$

and

$$\frac{\partial U_N}{\partial \phi} = - \left( \frac{\theta\alpha(\omega_S + a(1-\mu) - r_N)}{2+\alpha(\theta-1)} \right)^\theta \frac{\omega_S(\theta+1)(2-\alpha)}{2a\phi(1-\mu)(2+\alpha(\theta-1))} < 0. \quad (\text{A3})$$

The negative signs of both (A2) and (A3) in the interior solution are confirmed by applying the restriction  $r_N > \omega_S$  and by noticing that  $q_N > 0$  requires  $r_N < \bar{r} := \omega_S + a(1-\mu)$ .

From (15) we have

$$\frac{\partial \pi}{\partial \phi} = \omega_S \frac{(2-\alpha)^2 (r_N \mu - \omega_S) + \theta \alpha (1-\mu) (4-2\alpha + \theta \alpha) (a\mu - \omega_S)}{2a\mu\phi (1-\mu) (2+\alpha(\theta-1))^2}. \quad (\text{A4})$$

Setting  $r_N$  at the lower limit  $r_N$  yields  $\left. \frac{\partial \pi}{\partial \phi} \right|_{r_N = \underline{r}} = \frac{\omega_S \theta \alpha (a\mu - \omega_S)}{2\phi(\theta\alpha - \alpha + 2)a\mu} > 0$  if  $a\mu > \omega_S$ . Since  $\frac{\partial \pi}{\partial \phi}$  is monotonically increasing in  $r_N$ , we conclude that  $\frac{\partial \pi}{\partial \phi} > 0$  for all  $r_N \in (\underline{r}, \bar{r})$ .

From (15) we also have

$$\frac{\partial \pi}{\partial \mu} = \frac{(2 - \alpha)^2 (r_N \mu - \omega_S) (\omega_S (1 - 2\mu) + r_N \mu) + \theta \alpha (1 - \mu)^2 (a\mu - \omega_S) (\omega_S + a\mu) (4 - 2\alpha + \theta \alpha)}{4a\mu^2 (1 - \mu)^2 (2 + \alpha (\theta - 1))^2}. \quad (\text{A5})$$

It is easily confirmed that the numerator in (A5) is increasing in  $r_N$  if  $r_N > \omega_S$ , which is required to secure an interior solution for all  $\alpha \in (0, 1)$ . Setting  $r_N$  equal to the lower limit for an interior solution, we have that  $\left. \frac{\partial \pi}{\partial \mu} \right|_{r_N = \underline{r}} = \frac{(a\mu - \omega_S)\theta\alpha}{2\mu(2 + \alpha(\theta - 1))} > 0$  if  $a\mu > \omega_S$ . Due to the established monotonicity in  $r_N$ , we conclude that  $\frac{\partial \pi}{\partial \mu} > 0$  for all  $r_N \in (\underline{r}, \bar{r})$ . *Q.E.D.*

**Proof of Proposition 4.** (i) From (16)-(17), both second-order cross derivatives are positive if  $a(1 - \mu) > (r_N - \omega_S)$ . This condition always holds in an interior solution, since  $q_N > 0$  requires  $a(1 - \mu) > (w_N - \omega_S)$  and  $w_N > r_N$ .

(ii) From (19), a sufficient condition for  $\frac{\partial^2 \pi}{\partial w_S \partial \mu} < 0$  is that  $\omega_S + \mu(\mu r_N - 2\omega_S) > 0$ . The second term is convex in  $\mu$  with a minimum at  $\mu = \frac{\omega_S}{r_N}$ . For the minimum value of the second term, the condition is given by  $\omega_S \left(1 - \frac{\omega_S}{r_N}\right) > 0$ , which is always true since  $\omega_S > r_N$ ; thus  $\frac{\partial^2 \pi}{\partial w_S \partial \mu} < 0$ . From (18), the sign of  $\frac{\partial^2 \pi}{\partial w_S \partial \phi}$  depends on the sign of the numerator. It is straightforward to establish that the numerator is monotonically decreasing in  $\omega_S$  and that the sign is positive (negative) if  $\omega_S$  is below (above) a threshold value, given by

$$\hat{\omega} := \frac{\mu}{2} \left( \frac{a\alpha\theta(1 - \mu)(4 - \alpha(2 - \theta)) + r_N(2 - \alpha)^2}{\alpha\theta(1 - \mu)(4 - \alpha(2 - \theta)) + (2 - \alpha)^2} \right). \quad (\text{A6})$$

Thus,  $\frac{\partial^2 \pi}{\partial w_S \partial \phi} > (<) 0$  if  $\omega_S < (>) \hat{\omega}$ . *Q.E.D.*

**Proof of Proposition 5.** (i) From (26), the effects of  $a$ ,  $r_S$  and  $\phi$  follow immediately, while the effect of  $\mu$  is given by

$$\frac{\partial w_N}{\partial \mu} = -\frac{3(20a - \rho_S - 4)}{(16 - \mu)^2}, \quad (\text{A7})$$

which is clearly negative for  $a > 1$ .

(ii) From (27), the effects of  $a$ ,  $r_S$  and  $\phi$  follow immediately, while the effect of  $\mu$  is given by

$$\frac{\partial w_S}{\partial \mu} = \frac{(16a - 32a\mu + 12\rho_S + a\mu^2 + 48)\phi}{(16 - \mu)^2}. \quad (\text{A8})$$

The numerator is monotonically decreasing in  $a$  if  $\mu > 16 - 4\sqrt{15}$ . In this case the numerator is negative (thus  $\partial w_S/\partial\mu < 0$ ) if  $a > \frac{48+12\rho_S}{32\mu-\mu^2-16}$ . Otherwise, if  $\mu < 16 - 4\sqrt{15}$ , the numerator is positive (thus  $\partial w_S/\partial\mu > 0$ ) for all  $a > 1$ . *Q.E.D.*

**Proof of Proposition 6.** (i) Using (28), the signs of  $\frac{\partial U_N}{\partial\phi}$  and  $\frac{\partial U_S}{\partial\phi}$  are easily established from (31) and (32). From (33) we have

$$\frac{\partial\pi}{\partial\phi} = 9\rho_S \left( \frac{\mu(8a(1-\mu) + 8 + \mu) - (16 - 7\mu)\rho_S}{2\phi(16-\mu)^2(1-\mu)\mu a} \right). \quad (\text{A9})$$

Using the restriction  $\rho_S < \bar{\rho}$  (see eq. 30), we have

$$\mu(8a(1-\mu) + 8 + \mu) - (16 - 7\mu)\rho_S > \frac{\mu(1-\mu)(16-\mu)(a-1)}{4-\mu} > 0,$$

thus  $\frac{\partial\pi}{\partial\phi} > 0$ .

(ii) From (31) we have

$$\frac{\partial U_N}{\partial\mu} = \frac{3[3\rho_S - 4 + \mu + 4a(1-\mu)] [(54 - 9\mu)\rho_S - (40 + 4\mu + \mu^2 + 56a - 52a\mu - 4a\mu^2)]}{2(1-\mu)^2 a(16-\mu)^3}. \quad (\text{A10})$$

Using  $\rho_S < \bar{\rho}$  we have

$$\begin{aligned} & (54 - 9\mu)\rho_S - (40 + 4\mu + \mu^2 + 56a - 52a\mu - 4a\mu^2) \\ < & \frac{(1-\mu)(16-\mu)(5a\mu + \mu - 10 - 14a)}{4-\mu} < 0, \end{aligned}$$

thus  $\frac{\partial U_N}{\partial\mu} < 0$ .

From (32) we have

$$\frac{\partial U_S}{\partial\mu} = -\frac{3(3\mu + a\mu(1-\mu) - (4-\mu)\rho_S)}{2(16-\mu)^3 a(1-\mu)^2 \mu^2} \left[ \begin{array}{l} -\mu((31\mu - 16)(\mu - 1)a + 48 + 3\mu - 6\mu^2) \\ +\rho_S(-64 + 124\mu - 17\mu^2 + 2\mu^3) \end{array} \right]. \quad (\text{A11})$$

Assume that  $\frac{\partial U_S}{\partial \mu} < 0$ . This requires

$$-\mu \left( (31\mu - 16)(\mu - 1)a + 48 + 3\mu - 6\mu^2 \right) + \rho_S (-64 + 124\mu - 17\mu^2 + 2\mu^3) > 0,$$

or

$$(16 - 31\mu)(1 - \mu)a < \frac{\rho_S (-64 + 124\mu - 17\mu^2 + 2\mu^3) - \mu(48 + 3\mu - 6\mu^2)}{\mu}.$$

For  $\mu < \frac{16}{31}$ , this implies

$$a < \frac{\rho_S (-64 + 124\mu - 17\mu^2 + 2\mu^3) - \mu(48 + 3\mu - 6\mu^2)}{\mu(16 - 31\mu)(1 - \mu)},$$

which is negative for  $\mu < \frac{16}{31}$ . Thus  $\frac{\partial U_S}{\partial \mu}$  cannot be negative on this interval. For  $\mu > \frac{16}{31}$ , the above inequality becomes

$$a > \frac{\mu(48 + 3\mu - 6\mu^2) - \frac{r_S}{\phi} (-64 + 124\mu - 17\mu^2 + 2\mu^3)}{\mu(31\mu - 16)(1 - \mu)}.$$

What remains is to show that  $\frac{\partial \pi}{\partial \mu} > 0$ . We have

$$\frac{\partial \pi}{\partial \mu} = \frac{9N(a, \mu, \rho_S)}{4(16 - \mu)^3(1 - \mu)^2\mu^2 a}, \quad (\text{A12})$$

where

$$\begin{aligned} N(a, \mu, \rho_S) : &= \mu^2 \left( \begin{array}{l} 176 + 176a^2 + 190a\mu - 55\mu + 14\mu^2 - 343\mu a^2 \\ -96a - 92\mu^2 a + 158\mu^2 a^2 - 2a\mu^3 + 9\mu^3 a^2 \end{array} \right) \\ &+ \rho_S^2 (560\mu - 190\mu^2 + 21\mu^3 - 256) \\ &- 2\mu^2 \rho_S (16a - 23\mu - 2\mu^2 - 32a\mu + 16\mu^2 a + 160). \end{aligned} \quad (\text{A13})$$

It is now easily shown that  $N$  is increasing in  $a$ :

$$\frac{\partial N(a, \mu, \rho_S)}{\partial a} = 2\mu^2(1 - \mu)^2(176a - 48 - \mu + 9a\mu - 16\rho_S) > 0.$$

Using (28), we know that

$$a > \max \left\{ \frac{4 - \mu - 3\rho_S}{4(1 - \mu)}, \frac{(4 - \mu)\rho_S - 3\mu}{\mu(1 - \mu)} \right\}.$$

Which restriction is binding is determined by the parameters:

$$\frac{4 - \mu - 3\rho}{4(1 - \mu)} > \frac{(4 - \mu)\rho - 3\mu}{\mu(1 - \mu)}$$

iff

$$(16 - \mu)(\mu - \rho) > 0.$$

Thus, for  $\rho_S < \mu$ , the binding restriction is  $a > \frac{4 - \mu - 3\rho}{4(1 - \mu)}$ . Using the fact that  $N$  is monotonically increasing in  $a$ , we know that

$$N(a, \mu, \rho_S) > N\left(\frac{4 - \mu - 3\rho_S}{4(1 - \mu)}, \mu, \rho_S\right) = \frac{1}{16} (16 - \mu)^2 (33\rho_S\mu - 16\rho_S - \mu^2 - 16\mu) (\rho_S - \mu),$$

which is positive if  $\rho_S < \mu$ . Similarly, for  $\rho_S > \mu$ , the binding restriction is  $a > \frac{(4 - \mu)\rho_S - 3\mu}{\mu(1 - \mu)}$ , and thus

$$N(a, \mu, \rho_S) > N\left(\frac{(4 - \mu)\rho_S - 3\mu}{\mu(1 - \mu)}, \mu, \rho_S\right) = 2(16 - \mu)^2 (5\rho_S - (4 + \rho_S)\mu) (\rho_S - \mu) > 0.$$

Thus  $\frac{\partial \pi}{\partial \mu} > 0$ . *Q.E.D.*

**Proof of Proposition 7.** (i) Applying the restriction  $\rho \in (\underline{\rho}, \bar{\rho})$ , the positive sign of  $\Delta_\phi$  is easily confirmed.

(ii) From (35), since  $\mu(8 + \mu + 8a(1 - \mu)) - (16 - 7\mu)\rho_S > 0$  if  $\rho_S < \bar{\rho}$ , the sign of  $\Delta_\mu$  depends entirely on  $12\rho + 48 + a(-32\mu + \mu^2 + 16)$ , which is negative if  $\mu > 4(4 - \sqrt{15})$  and  $a > \frac{12\rho_S + 48}{32\mu - \mu^2 - 16}$ . In this case we are assured that any minimum wage will induce a lower incentive for product quality upgrading, because  $\frac{\partial \pi}{\partial \mu}|_{w_S - \text{const}}$  is decreasing in  $w_S$ , and we have used the lowest possible binding minimum wage to calculate  $\Delta_\mu$ . *Q.E.D.*

**Proof of Proposition 8.** (i) From (36),  $\frac{\partial^2 \pi}{\partial \phi \partial r_S}$  is positive (negative) if

$$\rho_S < (>) \frac{8\mu a(1-\mu) + 8\mu + \mu^2}{32 - 14\mu}.$$

Using (28),  $\frac{\partial^2 \pi}{\partial \phi \partial r_S}$  is always positive if  $a > \frac{64-38\mu+\mu^2}{6(1-\mu)\mu}$  and always negative if  $a < \frac{128-112\mu+11\mu^2}{32(4-5\mu+\mu^2)}$ .

(ii) From (37), we have

$$\frac{\partial^2 \pi}{\partial \mu \partial r_S} = 9 \left( \frac{2\rho_S (560\mu - 190\mu^2 + 21\mu^3 - 256) - 2\mu^2 (16a(1-\mu)^2 + 160 - \mu(23+2\mu))}{4\phi (16-\mu)^3 (1-\mu)^2 \mu^2 a} \right) \quad (\text{A14})$$

The numerator in (A14) is increasing in  $\rho_S$  for

$$\mu > \mu^* := -\frac{2}{63} \sqrt[3]{(208\,963 + 1134\sqrt{33\,949})} - \frac{410}{63 \sqrt[3]{(208\,963 + 1134\sqrt{33\,949})}} + \frac{190}{63}, \quad (\text{A15})$$

and decreasing in  $\rho_S$  otherwise. For  $\mu < \mu^*$ ,  $\frac{\partial^2 \pi}{\partial \mu \partial r_S}$  is always negative. For  $\mu > \mu^*$ ,  $\frac{\partial^2 \pi}{\partial \mu \partial r_S}$  is positive if  $\rho_S > \frac{\mu^2 (16a(1-\mu)^2 + 160 - \mu(23+2\mu))}{560\mu - 190\mu^2 + 21\mu^3 - 256}$ . However using the restriction  $\rho_S < \bar{\rho}$ , this cannot happen for  $a < \frac{48-14\mu+2\mu^2}{30\mu-5\mu^2-16}$ . *Q.E.D.*

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