A Theory of Outsourcing and Wage Decline

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Abstract

This paper develops a theory of outsourcing in which the circumstances under which factors of production can grab rents play the leading role. One factor has monopoly power (call this *labor*) while a second factor does not (call this *capital*). There are two kinds of production tasks: labor-intensive and capital-intensive. We show that if frictions limiting outsourcing are not too large, in equilibrium labor-intensive tasks are separated from capital-intensive tasks into distinct firms. When a capital intensive country is opened to free trade, outsourcing increases and labor rents decline. A decrease in outsourcing frictions lowers labor rents.

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1 Introduction

In the 1920s, Henry Ford famously built a factory in which the raw materials for steel went in on one end and finished automobiles went out the other. Extreme vertical integration like this is not the fashion today. Ford Motor has in recent years spun off a significant portion of its parts-making operations as a separate company, and General Motors has done the same. Within its assembly plants, General Motors is currently trying to outsource janitorial services and forklift operations to outside contractors.

This paper develops a theory of outsourcing in which the circumstances under which factors of production can grab rents play the leading role. One factor has some monopoly power (call this *labor*) while a second factor does not (call this *capital*). There are two kinds of production tasks: labor-intensive tasks and capital-intensive tasks. For example, auto part production (such as hand soldering of wire harnesses) tends to be labor-intensive, while final assembly of automobiles (with robots and huge machines) tends to be capital-intensive. In the model, all firms have the same abilities, so there is no motivation to specialize to exploit Ricardian comparative advantage. Furthermore, *outsourcing frictions* are incurred when the two kinds of tasks are not integrated in the same firm. So, in the absence of any monopoly power by labor, all firms are completely integrated, doing the labor-intensive and capital-intensive tasks as part of the same operation, and the outsourcing friction is avoided. However, if labor has monopoly power and if the outsourcing friction is not too large, outsourcing necessarily takes place, with some firms specializing in labor-intensive tasks and other firms specializing in capital-intensive tasks.

In order to describe when firms will be motivated to outsource some of their tasks rather than operating as an integrated unit, we need to formally define what distinguishes an integrated firm from a specialized one. A key feature of our analysis is what we call the *linkage constraint*; it is what binds together production decisions across various production lines in an integrated firm. Without the linkage constraint, integration would have no content as distinct production lines within the firm could be run as separate profit centers acting independently. It is the imposition of the linkage constraint that gives integration meaning in our analysis.

We motivate the linkage constraint two ways. First, we argue that it can emerge from technological considerations. It is the very act of coordinating production across production lines and running them the same way that can give rise to the savings in outsourcing frictions enjoyed by integrated firms. Second, we show it can emerge endogenously as a constraint that unions impose. Unions not only have control over the use of labor within a firm, they also have influence over the use of other inputs. For example, in the "sit-down" strike of General Motors in 1937, the United Auto Workers occupied factory equipment and blocked its use by "sitting" on it. In our model, if a integrated firm did not face the linkage constraint, it would tend to operate capital-intensive production lines at a faster rate than labor-intensive lines, because labor is taxed by unions, while the market for capital is competitive. We allow the union to block this from happening, to require that labor-intensive lines be run at least the same speed as capital-intensive lines. We show unions have an incentive to impose such a constraint.

The linkage constraint has an important implication for wage-setting behavior. It is well understood that labor demand is more elastic, the greater the labor share of a firm's overall factor bill. Hence labor demand for a firm specializing in the labor-intensive task will tend to be very elastic. Now consider an integrated firm with both labor-intensive and capital-intensive operations. On account of the linkage constraint, the separate lines are run as one integrated operation. Compared to a firm specializing only in labor tasks, labor is a smaller share of the overall factor bill for an integrated firm, so labor demand is less elastic. A union exploits the less elastic demand by setting a higher wage for the integrated firm than for a firm specializing in labor intensive tasks. In effect, the union of an integrated firm leverages its monopoly power on labor to also tax the capital usage of the firm.

A premise of this paper is that labor has market power while capital does not. There are good reasons to accept this premise. Workers can go on strike, and various job market protections in labor law can enhance labor bargaining power. Perhaps there will come a day when robots go on strike, but for now, business managers need not worry about capital walking off the job. In the formal analysis, we model market power narrowly as taking the form of a union with a monopoly on labor at the firm level. Our idea applies more broadly to include other sources of market power for workers, including job search frictions and potentially even social norms. Finally, while we call factor one labor and factor two capital, we can just as easily think of factor one as unionized unskilled labor (or blue-collar workers) and factor two as nonunion skilled labor (or white-collar workers).

We highlight three main results. First, we show that, in the absence of outsourcing frictions, and because of union wage setting, an integrated plant with any initial combination of capital-intensive tasks and labor-intensive tasks will always gain from spinning off production lines of either type to specialized plants, regardless of whether the divestiture is partial or complete. Hence, if there is technological change that eliminates or reduces outsourcing frictions (and a variety of studies have emphasized such change as discussed below), firms necessarily take advantage of this and choose to outsource.

Second, as outsourcing increases, the union wage falls. We note the example below of U.S. auto part plants that have been spun off from the integrated auto makers and note how the wages at these plants are much lower than what they used to be. More generally, the wage concessions made by union workers in recent years are a well-known story. Our theory shows how a reduction in outsourcing frictions can contribute to the wage decline of unionized, unskilled labor. We note that the mechanism at work here is very different from the mechanism at work in the "offshoring" papers mentioned below. In those papers, the elimination of the outsourcing friction makes it possible to allocate high-skill and capital-intensive tasks to the U.S., and low-skill tasks to foreign countries with low wage rates. Low-skill workers in the U.S. now have to compete with low-skilled workers elsewhere, driving down the blue-collar wage in the U.S. Our mechanism is different in that the advent of outsourcing introduces no new source of labor supply to compete with the current labor supply. Rather, the advent of outsourcing takes away the ability of unionized low-skill workers to leverage monopoly power to grab rents from capital and non-union high-skill workers.

Third, an exogenous decrease in the blue-collar wage before union markup increases the amount of outsourcing. There has been much discussion about the impact of technological change and increased international trade on depressing the wages of unskilled workers relative to skilled workers in recent decades. In our mechanism, these exogenous forces work towards an increase in outsourcing, compounding the troubles of blue-collar workers. In a related result, we put our model in an international context and show that if a rich (i.e. capital intensive) country is exposed to trade there will be an increase in outsourcing *within* the rich country. That is, there will be fewer integrated firms and more specialist labor firms and specialist capital firms within the rich country.

We turn now to a discussion of technological change that has facilitated outsourcing. Antràs, Garicano, and Rossi-Hansberg (2006) and Grossman and Rossi-Hansberg (2008), have argued that advances in information and transportation technology have permitted the separation of tasks previously required to be part of the same operation. When components are manufactured by separate operations, information costs must be incurred to ensure that separately produced components fit together both physically and in a timely production schedule (such as in *just-in-time* production). Japanese automobile manufacturers pioneered new ways to coordinate production with suppliers (see Womack, Jones, and Roos (1990) and Mair, Florida, and Kenney (1988)), and these methods have been adopted by U.S. manufacturers. This is an example of a decrease in the outsourcing friction. In recent years, there have been innovations in organizational forms and administrative structures, such as professional employer organizations that facilitate the segmentation of factors of production across different firm boundary lines. We broadly interpret these innovations as decreases in the friction.

Whether to integrate or outsource—the "make or buy" decision—is a classic topic in the theory of the firm. Much of the literature has focused on the role of incomplete contracts (Williamson (1979), Grossman and Hart (1986)).[1] In these models, economic agents cannot contractually commit to future behavior. Firm boundaries are drawn to optimally influence incentives, given the constraints of incomplete contracts. This kind of timing and commitment issue arises in our model. We make a crucial assumption that firms make long-run decisions about integration status before they engage in wage negotiations; the anticipation of lower wages on the labor-intensive task is precisely what induces firms to outsource. While our paper follows this literature in that timing and commitment play a key role, the model we consider is very different from those in the existing literature. This is especially true in the way we highlight and incorporate differences in factor composition across tasks.

In its industry equilibrium approach and its focus on what happens when trade frictions decline, the paper is close in spirit to the trade literature on offshoring (e.g., Grossman and Helpman (2005), Antràs, Garicano, and Rossi-Hansberg (2006)) and assignment theories of foreign direct investment (FDI) about who should specialize in which task (Nocke and Yeaple (2008)).[2] In its focus on specialization by tasks, the paper is particularly related to Grossman and Rossi-Hansberg (2008), and an early paper by Dixit and Grossman (1982). The result discussed above that an increase in exposure to trade can increase outsourcing is related to a similar finding in McLaren (2000). However, the mechanism here is completely different from the one at work in McLaren, which is about trade making markets less thin, reducing holdup opportunities. Here, opening a rich, capital and high skill intensive country to trade drives up the return to capital and high skill relative to low skill. This exacerbates the problem of unionized low-skill workers grabbing rents from non-union high-skill production lines and capital production lines in integrated firms. Firms have a greater incentive to separate out unskilled labor, to beat back this rent grabbing.

[1] A more recent literature examines how information flows affect integration decisions (Alonso, Dessein, and Matouschek (2008), Friebel and Raith (2006)).

[2] See also Liao (2010) for the analogous impact in an urban economics model.

A crucial implication of the theory is that wages in labor-intensive firms are lower than wages in integrated firms. This implication distinguishes our theory from a variety of other theories of outsourcing, such as standard comparative advantage theory, where wages to workers of the same ability are the same across firms. Some existing empirical work provides support for the wage implication of our theory. The building service industry (i.e., janitorial services) is a specialized, labor-intensive industry. Abraham (1990) and Dube and Kaplan (2008) show that building service employees employed in the business service sector (e.g., contract cleaning firms) receive substantially lower wages and benefits than employees doing the same jobs and with similar characteristics employed by manufacturing firms. We can think of such manufacturing firms as integrated operations, doing cleaning services for their facilities in addition to making things. Abraham and Taylor (1996) show that it is the higher-wage firms that are more likely to contract out cleaning services. Forbes and Lederman (2009) discuss how airlines spin off short routes to regional airlines because the pilots of these airlines are then less able to extract rents. This fits our model if short routes with small planes are less capital intensive than long-haul routes with large planes. Doellgast and Greer (2007) provide a case study of the German automobile industry to show how outsourcing parts has cut rents. We do not know of such a study for the U.S. automobile industry, but as mentioned in the first paragraph, there is anecdotal evidence that the same has happened in the United States. More specifically, General Motors (GM) spun off Delphi, its labor-intensive parts operations, and subsequently Delphi is trying to cut wages "to as little as $10 an hour from as much as $30."[3] GM spun off the parts operation American Axle in 1992, and subsequently American Axle succeeded in cutting wages by about a third.[4] As part of the plan to outsource janitorial services at GM assembly plants, the expectation is that wages to janitors would fall from $28 an hour for an in-house GM employee to around $12 an hour for an employee of a contract cleaning firm.[5]

The remainder of the paper is organized as follows. Section 2 lays out the model, and Section 3 determines equilibrium wage setting. Section 4 highlights the incentive to outsource, abstracting from the presence of outsourcing frictions. Section 5 takes outsourcing frictions into consideration and determines how the equilibrium amount of outsourcing depends upon model parameters. Section 6 shows how an reduction in outsourcing frictions reduces the union wage. Section 7 makes the linkage constraint an endogenous choice of the union.

[3] The quote is from the *New York Times*, November 19, 2005, "For a G.M. Family, the American Dream Vanishes," by Danny Hakim.

[4] See "American Axle Contract Ratified, Strike Ends," Reuters, May 22, 2008.

[5] See "GM to UAW: Let's Cut Costs," *Workforce Management: News in Brief*, April 16, 2007.

Section 8 concludes.

2 Model

We describe the technology and then explain how unions operate. Next we explain timing in the model and define equilibrium.

2.1 The Technology

We model an industry in which a final good is made out of a continuum of intermediate goods. Intermediates can be of two types, *labor-using* (denoted type L), and *capital-using*, (denoted type K). The different varieties of labor-using intermediates are indexed by $i \in [0, \lambda_L]$ and capital-using intermediates by $j \in [0, \lambda_K]$, where λ_L and λ_K are the number of varieties of each type. Exactly one of each of the $i \in [0, \lambda_L]$ labor-using intermediates and exactly one of each of the $j \in [0, \lambda_K]$ capital-using intermediates are required to create one unit of the final good. For example, if the final good is a car, the λ_L labor-using intermediates might include quality check, connecting the wiring, and security, while the λ_K capital-using intermediates might include body framing, body welding, and painting. Formally, q units of each variety $i \in [0, \lambda_L]$ and $j \in [0, \lambda_K]$ are required to produce q units of final good.

Let p_F denote the price of the final good. We begin with a firm-level analysis where p_F is taken as fixed. Later we will allow for the final good price p_F to be endogenous.

Intermediate goods are produced in *production lines*. A production line that employs y units of input produces

$$q = y^{\gamma} \tag{1}$$

units of output, where $0 < \gamma < 1$. For labor-using intermediates, y is in units of labor; for capital-using, y is in units of capital. We will refer to the input level y as the *line speed* of a particular production line.

We assume there is a unit measure of each variety of production line in fixed supply to the industry.

It is possible to combine production lines to create integrated firms. In the analysis there will be symmetry across labor-using lines and across capital-using lines. So for each firm, it is sufficient to keep track of the number n_L and n_K of production lines of each type that it operates. We will refer to the pair (n_L, n_K) as the *vertical structure* of a firm.

We allow for the integration of production lines within a firm to confer a potential benefit from savings on *outsourcing frictions*. It is intuitive that there might be cost savings from attaching production lines to each other and running them as an integrated operation. For example, perhaps by integrating lines, a firm can avoid an expenditure on some kind of packaging machinery that would otherwise be needed to transfer intermediates across the production lines of different operations. To simplify the analysis, we assume the transfer frictions take the form of fixed cost rather than marginal cost; e.g., if a production line is to be run as a specialist line, some additional setup expenditure must be incurred. Some of our results impose a specific assumption about the nature of this fixed cost and we explain this assumption below. Our main results can be extended to the case where the friction is a constant marginal cost, as we discuss below.

In exchange for the benefit of savings on outsourcing frictions, integrated firms are subjected to what we call the *linkage constraint* that all production lines be operated at the same line speed. In particular if y_L is the line speed of labor lines and y_K the line speed of capital lines, then $y_L = y_K$ for integrated firms.

We motivate the linkage constraint in two ways. The first motivation is that it arises as a technological constraint. Imagine that integrated production lines are physically attached as in an assembly line. It is intuitive that production lines attached this way might need to be run at the same line speed. A fully-integrated firm running each line to produce q units of intermediate good produces exactly enough intermediate to make q units of the final good. There are no leftover parts to be put in a spot market for someone else to finish. If instead there were leftover parts, this might lead to the outsourcing frictions discussed above, such as the installation of special packaging machinery to handle leftover parts. The precise coordination of all the production lines of an integrated plant can be viewed as the source of the gains from integration.

The second motivation is that the linkage constraint arises endogenously as a choice by the union. Suppose there is no technological constraint that y_L equal y_K, but now give the union the option to impose a constraint on the firm that $y_L \geq y_K$. We will show that the union in equilibrium will choose to impose this constraint and that it will be binding for the firm, $y_L = y_K$. This assumption captures the general notion that unions gain leverage not just over labor but also over the utilization of other inputs in a firm. For example, if a union calls a strike, all production lines of the firm may be shut down, both labor-using and capital-using. If a firm tries to operate capital-using lines at a high rate, and the labor-using lines at a low rate, the union can potentially make trouble for the firm, slowing down the capital using lines.

All of the results of this paper follow from the constraint that $y_L = y_K$ for integrated firms. If there were no linkage across production lines for integrated firms, then integration would have no impact on union wage-setting behavior, since the labor-using line of an integrated firm would behave in an identical fashion to a specialist firm with only labor-using lines. It is the linkage in production decisions across production lines that gives integration content.

For our baseline analysis, we simply impose the linkage constraint directly, using the technological motivation. This case is simpler, as it saves the step of analyzing the union's choice of whether or not to impose the linkage constraint. Later, in Section 7, we make choice of the constraint endogenous, and prove the union will want to impose the constraint.

2.2 Input Markets

Each firm is a price taker in the capital market. Let r denote the price of one unit of capital services.

The labor market is not competitive. Each firm has a union that acts as a monopolist over the supply of labor to the firm. The union at a particular firm buys labor on the open market at a competitive wage w° and resells it to the firm at a wage w of its choosing, pocketing the difference $w - w^{\circ}$. The firm then makes its input choices, taking w as given. This setup—where the union picks the wage and the firm picks the employment level—is called the "right-to-manage" model in the labor literature. The union operates at the plant level rather than the economy level. So the union at particular firm sets a wage that is specific to the particular firm.

2.3 Timing

Timing is in three stages. In stage 1 there is a competitive market in production lines. There is an initial endowment of production lines across entrepreneurs. The entrepreneurs then buy and sell production lines and assemble them into firms with a given vertical structure (n_L, n_K). At the end of stage 1, all production line capacity is allocated across firms and vertical structure is set. At the end of stage 1, any kind of fixed cost from outsourcing frictions is incurred as a function of vertical structure.

In stage 2, the union at each firm posts a wage. The union observes the firm's vertical structure (n_L, n_K) and the union sets a wage $w^*(n_L, n_K)$ conditional on this. In Section 7, we allow for the the linkage constraint to be a choice made by the union and we assume this decision is made in stage 2 at the same time as the wage is set.

In stage 3, firms make input and output decisions, taking as given input and output prices.

Specifically, let p_L be the price of a labor-using intermediate. Given symmetry, in equilibrium the price will be the same across all varieties of labor-using intermediates. Analogously define p_K. Due to the one-to-one fixed proportions and the fact that the final good is sold on a competitive market, the final output price must equal the sum of the component prices across the λ_L and λ_K varieties,

$$p_F = \lambda_L p_L + \lambda_K p_L. \tag{2}$$

Next consider a firm with vertical structure (n_L, n_K). Given the symmetry across labor lines and across capital lines and the linkage constraint to run labor lines and capital lines at the same speed, it produces the same amount of output of each of the intermediates that it produces. The price per unit of line speed summed over all the component products equals

$$p^*(n_L, n_K) = n_L p_L + n_K p_K. \tag{3}$$

In equilibrium, a firm in stage 3 with vertical structure (n_L, n_K) picks inputs to maximize profits, taking its output price $p^*(n_L, n_K)$ and wage $w^*(n_L, n_K)$ as given. In equilibrium, markets for intermediate goods must clear.

In equilibrium, in stage 2 the union at each firm picks the wage, anticipating the labor demand behavior of the firm in stage 3.

In equilibrium, in stage 1, firms are constructed by combining production lines to maximize the returns to the owners of the production lines. These decisions take into account union behavior in stage 2 and equilibrium output prices in stage 3.

3 Equilibrium Wage Setting

In this section, we work out how wages are determined. In order to examine union wage setting behavior, we first have to derive what a firm's labor demand behavior will be in stage 3.

Consider a firm in stage 3 with vertical structure (n_L, n_K). It faces an output price $p^*(n_L, n_K)$ and wage $w^*(n_L, n_K)$. The cost to the firm of operating at line speed y is

$c^*(n_L, n_K)y$, where

$$c^*(n_L, n_K) = w^*(n_L, n_K)n_L + rn_K \tag{4}$$

is the cost per unit of line speed. To see this, recall that each labor-using production line requires one unit of labor to run at a unit line speed; analogously, each capital-using line requires one capital unit.

When operating at line speed y, the firm produces $q = y^\gamma$ units of each intermediate. The profit of the firm is

$$\pi = py^\gamma - cy, \tag{5}$$

where for simplicity we leave out the dependence of p and c on the vertical structure (n_L, n_K). Maximizing profit as given in equation (5) yields an optimal line speed y^* and maximized profit π^*

$$y^* = \gamma^{\frac{1}{1-\gamma}} p^{\frac{1}{1-\gamma}} c^{-\frac{1}{1-\gamma}} \tag{6}$$

$$\pi^* = \phi p^{\frac{1}{1-\gamma}} c^{-\frac{\gamma}{1-\gamma}}, \tag{7}$$

for

$$\phi \equiv \gamma^{\frac{\gamma}{1-\gamma}} - \gamma^{\frac{1}{1-\gamma}}.$$

Now consider the problem of a union in stage 2 setting the wage for a firm with vertical structure (n_L, n_K). The wage choice w determines the unit line speed cost $c = wn_L + rn_K$. Substituting c in equation (6) gives total labor demand

$$l^D = n_L \times y^*,$$

i.e., the number of labor-using production lines times the line speed. The union obtains labor at the open-market rate w°. It sets the wage w to maximize the union rent

$$\begin{aligned} (w - w^\circ)\, l^D &= (w - w^\circ)\, n_L \times y^* \\ &= (w - w^\circ)\, n_L \gamma^{\frac{1}{1-\gamma}} p^{\frac{1}{1-\gamma}} (wn_L + rn_K)^{-\frac{1}{1-\gamma}}. \end{aligned} \tag{8}$$

Observe that the output price p enters in multiplicatively into the union objective function. This is convenient, as it implies the optimal union wage is independent of the output price. Maximizing equation (8) and taking the first-order condition, it is straightforward to derive the following formula for the optimal union wage:

$$w^* = \frac{w^\circ}{\gamma} + \frac{1-\gamma}{\gamma}\frac{n_K}{n_L}r \tag{9}$$

The first term is a markup over the union's marginal cost w° from the labor spot market. If there were no capital-using lines in the plant, i.e. $n_K = 0$, the second term would be zero and the wage would simply be the markup in the first term.

When there are capital-using lines at the plant, the second term is positive. The larger the ratio n_K/n_L of capital-using lines to labor-using lines, the higher the wage. This is a key point of the paper. The presence of the capital-using lines tends to make labor demand more inelastic. We can see this in equation (8) where we substitute in $(wn_L + rn_K)^{-\frac{1}{1-\gamma}}$ for $c^{-\frac{1}{1-\gamma}}$. The higher the ratio of capital to labor-using lines, the lower the percentage of labor costs in the overall factor bill for a given wage. So a given increase in wage has a smaller percentage impact on labor demand.

When the firm has a positive amount of labor-using lines, we can plug in the optimal wage given in equation (9) into cost equation (4) to obtain the unit line speed cost,

$$\begin{aligned} c^*(n_L, n_K) &= n_L w^* + n_K r \\ &= n_L \left[\frac{w^\circ}{\gamma} + \frac{1-\gamma}{\gamma}\frac{n_K}{n_L}r\right] + n_K r \\ &= \left[n_L \frac{w^\circ}{\gamma} + n_K \frac{r}{\gamma}\right], \text{ if } n_L > 0. \end{aligned} \tag{10}$$

If the firm has no labor-using lines, it faces no extortion from the union and its unit line speed cost is

$$c^*(n_L, n_K) = n_K r, \text{ if } n_L = 0. \tag{11}$$

Note there is a discontinuity in c^* at $n_L = 0$. The limit of the optimal line speed cost given in equation (10) as n_L goes to zero equals $\frac{1}{\gamma} n_K r$, and this is greater than the value (11) at 0. While n_L goes to zero, the union wage (9) goes to infinity.[6]

[6] If we tweak the model to put a cap $\bar{w}$ on the maximum wage that the union can set, then the discontinuity in cost as n_L goes to zero disappears. We view such a constraint as sensible. If $\bar{w}$ is set high enough, it won't have any impact on equilibrium outcomes, as firms won't chose vertical structures that result in extremely high wages. If $\bar{w}$ is set at an intermediate level, the cap can increase the incentive to outsource, as a firm can spin off labor lines to specialist firms with lower wages, without raising its own wage if it is already at the cap. Finally, if the cap is very low, in particular $\bar{w} \in (w^\circ, \frac{w^\circ}{\gamma})$, then all wages are at the cap regardless of vertical structure, and the incentive to outsource to impact wages disappears.

4 The Incentive to Outsource

This section presents the key result that—on account of the monopoly power in the labor market and the linkage in production between labor and capital lines for integrated firms—there is an incentive to outsource. In particular, we show that for any firm that is integrated with both capital-using and labor-using lines, if we don't take into account outsourcing frictions, there is a strict gain from selling off capital-using lines and from selling off labor-using lines. Of course, these gains must be weighed against outsourcing frictions that are incurred through these sell-offs.

Consider the problem of an entrepreneur in stage 1 with an initial endowment of $m_L > 0$ and $m_K > 0$ units of each type of production line. Recall that in stage 1, production lines can be reallocated across entrepreneurs to create firms. Let s_L and s_K denote a quantity of production lines that the entrepreneur sells off, relative to the endowment of (m_L, m_K), so that at the beginning of stage 2 (in which the union sets the wage), the resulting firm has

$$n_i = m_i - s_i \tag{12}$$

units of type i lines, $i \in \{L, K\}$. (If $s_i < 0$, the entrepreneur is acquiring lines.)

Define $v(s_L, s_K)$ to be equilibrium return to the entrepreneur as a function of her sell-off decision. For our purposes, it is useful to break this into three parts,

$$v(s_L, s_K) = v^{Resid\_Profit}(s_L, s_K) + v^{\text{Sell-off}}(s_L, s_K) + v^{Outsource\_Friction}(s_L, s_K),$$

The first term is the profit of the residual integrated firm net of sell-offs and excluding outsourcing frictions. The second term is what the entrepreneur collects from the sale of the production lines in the open market in stage 1. The third term accounts for any outsourcing frictions, including those resulting from any sell-offs in stage 1. (This term will be negative.) In this section, we put off discussion of $v^{Outsource\_Friction}(s_L, s_K)$ and focus on the first two terms.

To calculate the residual integrated firm profit $v^{Resid\_Profit}(s_L, s_K)$, we subtract out the sold-off lines, using equation (12), to get the residual vertical structure (n_L, n_K). This pins down the cost $c^*(n_L, n_K)$ per unit line speed (equation (10)), and output price $p^*(n_L, n_K)$

per unit (equation (3)). Plugging in unit price and cost into the profit formula (7) yields

$$v^{Resid\_Profit}(s_L, s_K) = \phi p^* (n_L, n_K)^{\frac{1}{1-\gamma}} c^*(n_L, n_K)^{-\frac{\gamma}{1-\gamma}}. \tag{13}$$

Next consider $v^{\text{Sell-off}}(s_L, s_K)$, the proceeds from the sell-offs. In general, the equilibrium market price of production lines will depend upon the particular specification of the outsourcing frictions and we work out a particular parameterization below.[7] However, for the purposes of this section, it is sufficient to derive a lower bound for equilibrium prices of production lines rather than derive the exact levels. In particular, for any production line there is the option of running it as a specialized operation so the market price must be least as high as the profit obtained from running it this way. A specialist firm using only capital has a unit line speed cost of $c_K = r$, as it escapes rent extraction by a union. A specialist firm that uses only labor has a unit cost of $c_L = w^{\circ}/\gamma$. Using equation (7), the profit from running a specialty operation of type i per production line is

$$\pi_i^{Spec} = \phi p_i^{\frac{1}{1-\gamma}} c_i^{-\frac{\gamma}{1-\gamma}}. \tag{14}$$

Since the market price of a type i production line is bounded from below by this, if follows that

$$\frac{\partial v^{\text{Sell-off}}(s_L, s_K)}{\partial s_i} \geq \pi_i^{Spec}. \tag{15}$$

We are now in a position to state the main result of this section.

Proposition 1. If a firm is integrated, then its equilibrium return excluding outsourcing frictions strictly increases in sell-offs of both labor- and capital-using production lines. Formally, for (s_L, s_K) such that for the residual firm $n_i = m_i - s_i > 0$ for $i \in \{L, K\}$, $v^{Resid\_Profit}(s_L, s_K) + v^{\text{Sell-off}}(s_L, s_K)$ strictly increases in s_L and s_K.

Proof. We prove the result for s_L. The derivation for s_K is analogous. Differentiating residual profit equation (13), using the sell-off condition (15), and dividing by the scalar ϕ,

[7] Note we define sell-off prices here to be exclusive of any oursourcing fixed cost. Nevertheless, the specification of the outsourcing friction can impact this price that excludes the friction. The parameterization of the outsourcing friction impacts the kind of integrated firms that are observed in equilibrium (e.g. what the ratio n_K/n_L is for integrated firms) and this in turn impacts the relative price of intermediates p_K/p_L which in turn impacts market prices of production lines.

it is sufficient to show that

$$-\frac{p_L}{1-\gamma}\left(\frac{p^*\left(n_L,n_K\right)}{c^*(n_L,n_K)}\right)^{\frac{\gamma}{1-\gamma}}+\frac{\gamma}{1-\gamma}\left(\frac{p^*\left(n_L,n_K\right)}{c^*(n_L,n_K)}\right)^{\frac{1}{1-\gamma}}\frac{w^\circ}{\gamma}+\frac{p_L^{\frac{1}{1-\gamma}}}{c_L^{\frac{\gamma}{1-\gamma}}}$$

is strictly positive when $n_L > 0$ and $n_K > 0$. (Note we use $\partial p^*/\partial n_L = p_L$ in the first term, $\partial c^*/\partial n_L = \frac{w^\circ}{\gamma}$ in the second term, and specialized profit equation (14) and inequality (15) in the third term.) Substituting in for p^* and c^* in the first term and $c_L = \frac{w^\circ}{\gamma}$ in the third term yields

$$-\frac{p_L}{1-\gamma}\left(\gamma\frac{n_Lp_L+n_Kp_K}{n_Lw^\circ+n_Kr}\right)^{\frac{\gamma}{1-\gamma}}+\frac{\gamma}{1-\gamma}\left(\gamma\frac{n_Lp_L+n_Kp_K}{n_Lw^\circ+n_Kr}\right)^{\frac{1}{1-\gamma}}\frac{w^\circ}{\gamma}+\frac{p_L^{\frac{1}{1-\gamma}}}{\left(\frac{w^\circ}{\gamma}\right)^{\frac{\gamma}{1-\gamma}}}.$$

Define a variable ζ such that

$$p_K \equiv \zeta\gamma\frac{r}{w^\circ}p_L.$$

Substituting p_K into the above, and dividing through by $\frac{1}{1-\gamma}p_L^{\frac{1}{1-\gamma}}\left(\frac{w^\circ}{\gamma}\right)^{-\frac{\gamma}{1-\gamma}}$, it is sufficient to show that the following is strictly positive,

$$-\left(\frac{n_Lw^\circ+n_Kr\zeta\gamma}{n_Lw^\circ+n_Kr}\right)^{\frac{\gamma}{1-\gamma}}+\gamma\left(\frac{n_Lw^\circ+n_Kr\zeta\gamma}{n_Lw^\circ+n_Kr}\right)^{\frac{1}{1-\gamma}}+1-\gamma.$$

Defining

$$\theta \equiv \frac{n_Kr}{n_Lw^\circ+n_Kr},$$

it is sufficient to show

$$G(\theta,\zeta,\gamma) = -\left(1-\theta+\theta\zeta\gamma\right)^{\frac{\gamma}{1-\gamma}}+\gamma\left(1-\theta+\theta\zeta\gamma\right)^{\frac{1}{1-\gamma}}+1-\gamma>0,$$

for $\theta\in(0,1)$, $\gamma\in(0,1)$, and $\zeta>0$.

At $\theta = 0$, it is immediate that $G = 0$. Straightforward differentiation shows that G strictly increases in θ. This proves $G > 0$, for $\theta > 0$, completing the proof for s_L. Q.E.D.

Proposition 1 says that an integrated firm that has both capital-using and labor-using production lines has a strictly positive incentive to sell off both kinds of production lines, not taking into account any outsourcing frictions. To understand the result, it is useful to recall the equilibrium unit cost function

$$c^*(n_L, n_K) = n_L \frac{w^\circ}{\gamma} + n_K \frac{r}{\gamma}, \text{ if } n_L > 0$$

of an integrated firm, reported earlier as equation (10). In effect, the union is adding a markup $\frac{1}{\gamma}$ to the use of capital as well as to labor. Exploiting the linkage constraint, the the union extends its monopoly from labor to levy a tax on all inputs of the firm.

It is straightforward to see the benefit to the integrated firm of selling off a capital-using line. The specialist capital firm that the line is transferred to pays r for capital, escaping the marked-up value $\frac{r}{\gamma}$ that the integrated firm effectively pays. The benefit to selling off labor lines is more subtle, because, at the margin, the price of labor is effectively $\frac{w^\circ}{\gamma}$ for both the integrated firm and the labor specialist. The source of the gain here is that a sold-off labor line can escape the linkage constraint. In particular, if the labor line stays within integrated firm, then production on the labor line is tied to production on capital lines that are being taxed and therefore being distorted to inefficiently low levels. The lower is n_K/n_L, the less the relative importance of the distortion and the less the gain from selling off a labor line. In the limit where $n_K/n_L = 0$, there is no gain from selling off a labor line. (This is the case of $\theta = 0$ in the proof.)

An immediate implication of Proposition 1 is

Proposition 2. Assume there are no outsourcing frictions, i.e., $v^{Outsource\_Friction}(s_L, s_K) = 0$. In equilibrium, there will be no integration of labor and capital-using lines within the same firms.

Suppose there are no unions so that firms pay the spot-market wage w°. In this case, if there are no outsourcing frictions, then vertical structure is indeterminate. It doesn't make any difference how production lines are combined. Once we put in the union, there is a strict incentive to keep labor-using and capital-using lines separate.

We conclude this section with two comments. First, we can generalize functional forms. In particular, suppose there are two types of production lines such that the line speed of type $i \in \{L, K\}$ equals

$$y_i = A_i l^{\alpha_i} k^{1-\alpha_i},$$

for labor and capital inputs l and k, for $\alpha_L > \alpha_K$, so line L is more labor intensive than line K. Setting $\alpha_L = 1$ and $\alpha_K = 0$, and $A_L = A_K = 1$, corresponds to our benchmark model.

We discuss the following result in the separate Technical Appendix. Suppose the equilibrium intermediate good prices p_L and p_K are such that specialist production lines of each type run at the same line speed (so when we aggregate the specialist output to make final goods there are no left-over parts, i.e., we have market clearing among specialist firms). Take a firm that initially has vertical structure (m_L, m_K) that is integrated, $m_L > 0$ and $m_K > 0$. Using numerical analysis, we show that the profit of completely selling off the entire firm to specialist firms ($s_L = m_L$ and $s_K = s_K$ in the above notation), strictly dominates remaining at the initial vertical structure. Therefore, without outsourcing frictions, firms have a strict preference to be specialists.

We show that at these prices, the profit of an integrated firm with vertical structure (n_L, n_K), for $n_L > 0$, $n_K > 0$, is strictly less than the combined profit of n_L specialist labor firms and n_K specialist capital firms (again, ignoring outsourcing frictions). Straightforward numerical analysis shows our results continue to hold if the two types have different labor intensities ($\alpha_L > \alpha_K$). In particular, we can show that—excluding any outsourcing frictions—firms have a strict preference to spin off production lines to specialized firms, rather than be vertically integrated. The technical appendix provides details. However, it is necessary for us to apply numerical analysis, as the expressions are too complex for analytical results.

Second, recall outsourcing frictions are assumed to impact fixed cost rather than marginal cost. This simplifies things, as fixed-cost frictions don't impact pricing in stage 3, while frictions that vary with the level of output do. It is worth nothing, however, that if we impose outsourcing frictions that are of the "iceberg" variety, i.e., they come in the form of a proportional loss in output, then equilibrium wage setting behavior as a function of vertical structure is exactly the same as in Section 3, and the expressions for wage in equation (9) and cost in equation (10) are unchanged.[8] Thus the wage incentives for outsourcing are exactly the same.

[8] Recall that output price enters multiplicatively in the union problem, so an iceberg friction factors out and doesn't impact the optimal union wage.

5 Equilibrium with Outsourcing Frictions with an Application to Trade

We now determine equilibrium, taking outsourcing frictions into account. At this point, it is necessary to specify details about the friction. There are many ways this could be done. (And note that the results of the previous 4 sections, which did not assume a particular structure for the outsourcing friction, would still hold.) For example, the intermediate goods (or tasks) could vary in the difficulty with which they could be outsourced, so that parts assembly or floor mopping could easily be spun off to specialist producers, while seat installation and connecting the wiring needed to be done in an integrated operation.

However, for the sake of simplicity and tractability, we focus on the following simple structure. Assume that capital-using lines can be physically attached to labor-using lines on a one-to-one basis in an integrated firm. If a capital line is operated unattached, an outsourcing friction x must be incurred, in units of final consumption good. If the capital line is attached to a labor line, the friction x is avoided. The friction is a random variable that varies across capital-using lines. The distribution of x is same across all different varieties of capital-using lines; this preserves symmetry, simplifying exposition. Let the distribution of x be denoted $F(x)$, with support $[0, \bar{x}]$ and density $f(x)$. Finally, it simplifies matters if the variety of production lines is the same for each type and normalized to one, $\lambda_L = \lambda_K = 1$.

In the equilibrium of the model, for any integrated firm it must be that the ratio of capital lines to labor lines is exactly one-to-one, $n_L = n_K$. To see this, suppose $n_L > n_K$ for an integrated firm. Since capital lines are attached to labor lines on a one-to-one basis, there are extra labor lines that can be outsourced with no change in outsourcing frictions. Proposition 1 implies the firm would be strictly better off with such outsourcing, a contradiction. Similarly, if $n_L < n_K$, we get a contradiction. We can use this result that integrated firms are necessarily one-to-one to obtain the following characterization of equilibrium.

Proposition 3. Fix p_F, w°, and r, and take them as parameters (i.e. there is a perfectly elastic final good demand, and perfectly elastic supply of inputs). There is a unique equilibrium of the industry that has the following properties.

(i) Define the transfer friction cutoff $\hat{x}$ by

$$p_F \hat{x} \equiv \phi p_F^{\frac{1}{1-\gamma}} \left[\frac{w^\circ}{\gamma} + r \right]^{-\frac{\gamma}{1-\gamma}} - \phi p_F^{\frac{1}{1-\gamma}} \left(\frac{w^\circ}{\gamma} + \frac{r}{\gamma} \right)^{-\frac{\gamma}{1-\gamma}}. \tag{16}$$

All capital lines with transfer friction $x > \hat{x}$ are allocated to integrated plants with an equal number of labor lines. Thus a fraction $1 - F(\hat{x})$ of capital and labor lines are integrated. The remaining fraction $F(\hat{x})$ capital-using lines are operated in firms that specialize in capital. Analogously, the remaining fraction $F(\hat{x})$ labor-using lines are operated in firms that specialize in labor.

(ii) The integration cutoff $\hat{x}$ is strictly decreasing in w°, and strictly increasing in r and p_F.

(iii) Union rents are strictly higher in vertically integrated plants compared to specialist labor plants, i.e.,

$$(w_v - w^\circ)\, l_v > (w_s - w^\circ)\, l_s,$$

where l_v and l_s are the equilibrium labor demand of vertically integrated and speciality labor plants, and w_v and w_s are the wages.

Proof. See appendix.

The appendix provides the formal proof, but the main argument is straightforward. The left-hand side of equation (16) is the outsourcing friction incurred by the marginal outsourcer. (Recall the units of the friction are in terms of the final good.) The right-hand side of equation (16) is the gain from outsourcing. Specifically, the first term is the combined profit of a labor line and a capital line when run as speciality firms. (Recall equation (7).) Operating this way, the effective tax on capital is avoided. The second term subtracts the profit from running the two lines as an integrated operation, paying the effective markup on capital. Only when the friction exceeds this difference will integration take place.

According to part (ii) of the result, the equilibrium amount of vertical integration goes down with either an increase in the rental rate r or a decrease in the open-market wage w°. This is an intuitive result, because the whole point of paying the transfer friction to set up a specialized firm is to avoid taxation of capital by the union. The issue about taxation of capital is relatively more important the higher is r and the lower is w°. Also, the higher the final good price p_F, the more firms will want to invest in vertical disintegration to limit union power to tax.

We can put the results of Proposition 3 into an international trade context with two sectors. We refer to the final good we have been focusing on as *sector one.* In addition, there is *sector two* that makes a labor-intensive good which we will take as the numeraire. For simplicity, assume one unit of labor makes one unit of sector two good, so $w^{\circ} = 1$. Suppose labor and capital are not traded. (Recall we can interpret high skill labor as capital). Suppose the sector one final good can be traded, as well as the sector two good. However, intermediate goods in sector one cannot be traded; i.e., offshoring of labor-intensive components is not possible.

Suppose we take a country that is rich, i.e., it has a high capital-to-labor ratio relative to the rest of the world. If we open the rich country up to free trade with the rest of the world, it will tend to specialize in the capital-intensive sector one good and trade it for labor-intensive sector two good. As the rest of the world is capital scarce, trade will tend to drive up r and p_F in the rich country, while $w^{\circ} = 1$ stays fixed at the numeraire. Part (ii) of Proposition 3 then implies that the equilibrium amount of outsourcing strictly increases from exposure to trade.

Opening the capital-rich country to trade has the usual negative impact on workers of reducing the real wage, as p_F rises relative to w°. In addition there is an ambiguous impact on total union rents collected. On one hand, there is a force of decline as there is more outsourcing and union rents are lower at specialized plants than integrated plants (part (iii) of Proposition 3). On the other hand, there is a force of increase as union rents at plants that remain integrated increase as p_F and r increase.

6 A Decline in the Outsourcing Friction and Endogenous Output Price and Factor Prices

Up to this point the final good price p_F, the open-market wage w°, and the capital rental price r have been taken as parameters. In this section, they are all endogenous. Let $Q_F = D(p_F)$ be the demand curve for the final good and assume it is strictly downward sloping and that $D(p_F) > 0$ for all $p_F > 0$. Let $Y_L = S_L(w^{\circ})$ be the supply curve for labor at the open-market wage w° and $Y_K = S_K(r)$ be the supply curve for capital, and assume both are strictly upward sloping.

Our interest is on the impact of exogenous technological change facilitating outsourcing on the market equilibrium. The introduction cites a variety of papers that has emphasized the importance of this kind of technological change in recent years. Suppose that initially outsourcing frictions are prohibitively expensive so the only possibility is full integration of labor-using and capital-using production lines. After technological change, suppose for simplicity all frictions are reduced to zero. Proposition 2 implies that after the technological change, there will be complete vertical disintegration of labor-using and capital-using production lines. Proposition 4 below summarizes the equilibrium impact of the emergence of outsourcing. Note the advent of outsourcing actually increases the equilibrium open-market wage, as the industry expands with the dilution of union power and the open-market wage is increased to draw more labor in. Nevertheless, the impact of outsourcing on the wage including the union markup is unambiguously negative.

Proposition 4. (i) There is a unique equilibrium set of prices $(p_{F,v}, w_v^{\circ}, r_v)$ in the initial regime with full vertical integration and a unique equilibrium set of prices $(p_{F,s}, w_s^{\circ}, r_s)$ in the second regime with specialization, with $p_{F,v} > p_{F,s}$, $w_v^{\circ} < w_s^{\circ}$, and $r_v < r_s$. (ii) The wage including the union markup is strictly lower in the second regime with specialization, $w_v > w_s$.

Proof of (i) Let y_v be the line speed in the vertical integration regime. The final good price and input prices solve the market clearing conditions,

$$\begin{aligned} y_v^{\gamma} &= D(p_{F,v}), \\ \lambda_L y_v &= S(w_v^{\circ}), \\ \lambda_K y_v &= S(r_v), \end{aligned}$$

and the firm optimal line speed equation (6)

$$y_v = \gamma^{\frac{1}{1-\gamma}} p_{F,v}^{\frac{1}{1-\gamma}} \left(\lambda_L \frac{w_v^{\circ}}{\gamma} + \lambda_K \frac{r_v}{\gamma} \right)^{-\frac{1}{1-\gamma}}, \tag{17}$$

where we substitute in the unit line speed cost c^* from equation (10) for a completely integrated firm (i.e. $n_L = \lambda_L$, $n_K = \lambda_K$). Invert the market clearing conditions to make $p_{F,v}$, w_v°, and r_v, monotonic functions of y_v and substitute these into the right-hand-side of equation (17) and vary y_v. The right-hand side is bounded above zero in the limit as y_v goes to 0 and is strictly decreasing. Hence, there is a unique equilibrium line speed y_v. In the specialization regime, the market clearing conditions are analogous and the optimal line speed condition is

$$y_s = \gamma^{\frac{1}{1-\gamma}} p_{F,s}^{\frac{1}{1-\gamma}} \left(\lambda_L \frac{w_s^\circ}{\gamma} + \lambda_K r_s \right)^{-\frac{1}{1-\gamma}}, \tag{18}$$

which is the same as in equation (17) except capital is no longer being taxed. It is immediate that there is a unique solution and that $y_v < y_s$, implying $p_{F,v} > p_{F,s}$, $w_v^\circ < w_s^\circ$, and $r_v < r_s$, as claimed.

Proof of (ii). Since $p_{F,v} > p_{F,s}$, but still $y_v < y_s$, from equations (17) and (18) it must be that

$$\lambda_L \frac{w_v^\circ}{\gamma} + \lambda_K \frac{r_v}{\gamma} > \lambda_L \frac{w_s^\circ}{\gamma} + \lambda_K r_s,$$

or, dividing through by λ_L and subtracting $(\lambda_K/\lambda_L) r_S$ from both sides

$$\frac{w_v^\circ}{\gamma} + \frac{\lambda_K}{\lambda_L} \frac{r_v}{\gamma} - \frac{\lambda_K}{\lambda_L} r_s > \frac{w_s^\circ}{\gamma}.$$

Since $r_s > r_v$, it must be that

$$\frac{w_v^\circ}{\gamma} + \frac{\lambda_K}{\lambda_L} \frac{r_v}{\gamma} - \frac{\lambda_K}{\lambda_L} r_v > \frac{w_s^\circ}{\gamma},$$

or

$$w_v = \frac{w_v^\circ}{\gamma} + \frac{1-\gamma}{\gamma} \frac{\lambda_K}{\lambda_L} \frac{r_v}{\gamma} > \frac{w_s^\circ}{\gamma} = w_s,$$

where the equalities use formula (9) for the union wage. Hence, the equilibrium wage with union markup is strictly lower in the second regime with specialization, as claimed. *Q.E.D.*

7 Making the Linkage Constraint Endogenous

As noted earlier, the linkage constraint that $y_L = y_K$ for integrated firms is crucial for all of our results. For our baseline analysis we motivate it on technological grounds. Here we consider the second motivation discussed earlier, that it arises as an endogenous choice by the union. Specifically, assume now that at stage 2, the union of an integrated firm can choose to impose a constraint that no labor-using line run slower than any capital-using line. Given the symmetry of labor lines, the firm will run to desire to run each labor line at the same speed. Analogously, given the symmetry of capital lines, the firm will desire to run each capital line at the same speed. So effectively the constraint that the union can choose to impose is that $y_L \geq y_K$. Assume that otherwise there is no technological constraint linking production lines of integrated plants. Assume for now that if the union chooses to impose the constraint then it is binding, $y_L = y_K$. We will show this is true. Moreover, if the union doesn't impose the constraint then the firm will set $y_L < y_K$.

With the linkage constraint imposed and $y_L = y_K$, all of our earlier calculations continue to be valid. In particular, substituting the solution for the optimal wage in equation (9) into the formula for the union rent given in equation (8), we obtain a maximized union rent of

$$UnionRent(n_L, n_K) = \left(\frac{1-\gamma}{\gamma}\right)\left(\frac{n_L p_L + n_K p_K}{(w^\circ n_L + n_K r)^\gamma}\right)^{\frac{1}{1-\gamma}}. \tag{19}$$

Next suppose the union does not impose the linkage constraint. Without the constraint, the production decisions by the firm on labor-using lines are completely distinct from decisions on capital-using lines. Hence, the labor lines are managed the same way they would be if there were no capital lines, i.e., a firm with vertical structure (n_L, n_K) behaves the same in its labor demand as a firm with vertical structure $(n_L, 0)$. The optimal wage is then $\frac{w^\circ}{\gamma}$ and the union rent is then $UnionRent(n_L, 0)$. The union prefers to impose the linkage constraint if $UnionRent(n_L, n_K) > UnionRent(n_L, 0)$. Our result is

Proposition 5. Consider the unique equilibrium in Section 5 where outsourcing frictions are explicitly specified. (i) If a given integrated firm were offered the equilibrium wage for its type but were not required to satisfy the linkage constraint, it would set the capital line speed higher than the labor line speed, $y_K > y_L$. (ii) If unions of integrated plants are given a choice of whether or not to impose the linkage constraint, they strictly prefer to impose it, i.e., $UnionRent(n_L, n_K) > UnionRent(n_L, 0)$ for any $n_L > 0$ and $n_K > 0$.

Proof. See appendix.

8 Concluding Remarks

We have developed a model that highlights the incentive for firms to outsource, keeping labor-intensive tasks isolated from capital-intensive tasks, thereby preventing a union from leveraging its market power over labor onto the complementary activity. A main result is that, absent any outsourcing frictions, integrated plants have an incentive to shed both labor-intensive and capital-intensive tasks to specialized firms. Furthermore, the incentive to outsource is greater, the lower are wages prior to union markup, and the higher the rental rate on capital and the higher the final good price. Thus, a rich, capital intensive country that is opened up to trade will experience an increase in outsourcing. Lastly, while technological change facilitating outsourcing raises the wage before union markup, it decreases the wage inclusive of union markup.

We have made a number of simplifying assumptions along the way to make the analysis tractable. For example, we assume that labor-intensive lines use only labor and capital-intensive lines only capital, as this gives us convenient analytic expressions. Our key result continues to hold under general Cobb-Douglas production functions, as the numerical analysis discussed in the technical appendix explains. As another example, we simplify by assuming intermediates aggregate to the final good in a Leontief fashion. While we haven't worked through alternative formulations, we have no reason to believe that the Leontief assumption is essential for our results.

The linkage constraint is essential for our results. That is, it is crucial that the production decisions on labor lines are linked to production decisions on capital lines of integrated firms. This gives integration content. We have imposed the constraint in a stark fashion, requiring equality of line speeds within integrated firms in one formulation and making the constraint an endogenous choice in a second formulation. On can imagine more flexible ways to impose linkage, with our formulation being an extreme case.

Our paper presents a variety of directions for future research. We have abstracted away from the theory of comparative advantage, but a richer model might also take this into account. We've also assumed that all labor lines in the model are unionized, but one can imagine a model with heterogeneity in the extent of unionization, or which even makes the unionization decision endogenous. As a final example, we have assumed that all outsourcing takes place domestically even when the model is opened to international trade; however, one could also extend the model to think about offshoring.

Appendix

Proof of Proposition 3

We begin with some background calculations. As argued in the text, all integrated firms will have a vertical structure with a one to one ratio, $n_L = n_K$. Thus they will all face the same wage

$$w_v = \frac{w^\circ}{\gamma} + \frac{1-\gamma}{\gamma}\frac{n_K}{n_L} r = \frac{w^\circ}{\gamma} + \frac{1-\gamma}{\gamma} r \tag{20}$$

and will run at the same line speed. Since final goods are constructed with capital and labor intermediates with a one-to-one ratio, and since the distribution of the outsourcing friction x is i.i.d. across varieties of labor and capital production lines, without loss of generality, we can assume that integrated plants are fully integrated, $n_L = \lambda_L$, $n_K = \lambda_K$. Hence, the market for intermediate goods that are traded will be entirely supplied by specialist firms. Let y_i be the line speed of a specialist firm of type i. Since the intermediates are combined one-for-one to make final goods, market clearing requires that $y_L = y_K$. Using formula (6) for the optimal line speed, this implies

$$\gamma^{\frac{1}{1-\gamma}} p_L^{\frac{1}{1-\gamma}} c_L^{-\frac{1}{1-\gamma}} = \gamma^{\frac{1}{1-\gamma}} p_K^{\frac{1}{1-\gamma}} c_K^{-\frac{1}{1-\gamma}}$$

or

$$\frac{p_K}{p_L} = \frac{c_K}{c_L} = \gamma \frac{r}{w^\circ}, \tag{21}$$

using the unit costs $c_K = r$ and $c_L = \frac{w^\circ}{\gamma}$ for specialty firms.

Proof of part (i). The main text provides the argument for why there is a unique cutoff $\hat{x}$ that defines the point of indifference between outsourcing and not outsourcing and we restate the equation for $\hat{x}$ here for convenience,

$$p_F \hat{x} \equiv \phi p_F^{\frac{1}{1-\gamma}} \left[\frac{w^\circ}{\gamma} + r\right]^{-\frac{\gamma}{1-\gamma}} - \phi p_F^{\frac{1}{1-\gamma}} \left(\frac{w^\circ}{\gamma} + \frac{r}{\gamma}\right)^{-\frac{\gamma}{1-\gamma}}. \tag{22}$$

Proof of part (ii). Follows from straightforward differentiation of (22)

Proof of part (iii). We need to show that rents are strictly higher in vertically integrated plants compared to specialist labor plants, i.e.,

$$(w_v - w^\circ)\, l_v > (w_s - w^\circ)\, l_s.$$

Suppose the union of an integrated plant were to set wage equal to $w_s = \frac{w^\circ}{\gamma}$, rather than w_v as defined above. If the integrated plant faced w_s and if it were not subject to the linkage constraint, the labor-using line and the capital-using line of the integrated plant would behave exactly like their respective specialty plant counterparts. But since the line speeds of speciality plants are equalized, $y_L = y_K$ as discussed above, the linkage constraint that we have ignored for the time being would automatically be satisfied. Therefore, by setting wage w_s to an integrated plant, the union would obtain the same rents as it would get from a specialty plant. Since the union optimally chooses $w_v > w_s$, the rent that it obtains from an integrated plant must be strictly higher than this. *Q.E.D.*

Proof of Proposition 5

Proof of Part (i). We need to show that if an integrated firm were to offer the equilibrium wage for its type (this is w_v defined above in the proof of Proposition 3), but were not required to satisfy the linkage constraint, it would set the capital line speed higher than the labor line speed, $y_K > y_L$. Recall that in the proof of part (iii) of Proposition 3 above, we showed that if an integrated firm were offered a wage of w_s and were not subject to the linkage constraint, then it would set $y_K = y_L$. Now if we continued to not impose the linkage constraint on this firm, but raised the wage to $w_v > w_s$, the firm's optimal choice of y_K would remain unchanged (since p_K and r stays fixed), but it would choose to lower the line speed of the labor-using line. This proves part (i).

Proof of Part (ii). We need to show that for $n_L > 0$ and $n_K > 0$,

$$\mathit{UnionRent}(n_L, n_K) > \mathit{UnionRent}(n_L, 0).$$

Using formula (19) for the union rent, this is equivalent to showing that

$$\frac{n_L p_L + n_K p_K}{(w^\circ n_L + n_K r)^\gamma} > \frac{n_L p_L}{(w^\circ n_L)^\gamma}.$$

Dividing through by p_L, substituting in formula (21) for the equilibrium value of p_K/p_L, and then multiplying through by w°, we need to show

$$\frac{w^\circ n_L + \gamma n_K r}{(w^\circ n_L + n_K r)^\gamma} > \frac{w^\circ n_L}{(w^\circ n_L)^\gamma},$$

or

$$1 + \gamma z > (1 + z)^\gamma,$$

for z defined by

$$z \equiv \frac{n_K r}{n_L w^\circ}.$$

This follows because $G(z) \equiv 1 + \gamma z - (1 + z)^\gamma$ satisfies $G(0) = 0$ and $G'(z) > 0$ for $z > 0$ and $\gamma \in (0, 1)$, as can be readily verified. *Q.E.D.*

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