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Trading Tasks: A Simple Theory of Offshoring

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We propose a theory of the global production process that focuses on tradeable tasks, and use it to study how falling costs of offshoring affect factor prices in the source country. We identify a productivity effect of task trade that benefits the factor whose tasks are more easily moved offshore. In the light of this effect, reductions in the cost of trading tasks can generate shared gains for all domestic factors, in contrast to the distributional conflict that typically results from reductions in the cost of trading goods. (*JEL* F11, F16)

The nature of international trade is changing. For centuries, trade mostly entailed an exchange of *goods*. Now it increasingly involves bits of value being added in many different locations, or what might be called *trade in tasks*. Revolutionary advances in transportation and communications technology have weakened the link between labor specialization and geographic concentration, making it increasingly viable to separate tasks in time and space. When instructions can be delivered instantaneously, components and unfinished goods can be moved quickly and cheaply, and the output of many tasks can be conveyed electronically, firms can take advantage of factor cost disparities in different countries without sacrificing the gains from specialization. The result has been a boom in "offshoring" of both manufacturing tasks and other business functions.[1]

In this paper, we develop a simple and tractable model of offshoring based on the tradeable tasks. We conceptualize production in terms of the many tasks that must be performed by each factor of production. A firm can perform each of the continuum of tasks required for the realization of its product either in close proximity to its headquarters or at an offshore location. Offshoring may be attractive, if some factors can be hired more cheaply abroad than at home, but it also is costly, because remote performance of a task limits the opportunities for monitoring and coordinating workers.[2] To capture this aspect of reality, our model features heterogeneous offshoring costs for the various tasks. In each industry, firms choose the geographic organization

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[1] The global disintegration of the production process has been documented by José M. Campa and Linda S. Goldberg (1997), David Hummels, Dana Rapoport and Kei-Mu Yi (1998), Alexander J. Yeats (2001), Hummels, Jun Ishii, and Yi (2001), and Gordon H. Hanson, Raymond J. Mataloni, and Matthew J. Slaughter (2001, 2005), among others.

[2] Several authors have sought to identify the characteristics of tasks that are good candidates for offshoring. For example, Frank Levy and Richard Murnane (2004) have distinguished "routine" and "nonroutine" tasks, following the lead of David Autor, Levy, and Murnane (2003). Edward E. Leamer and Michael Storper (2001) draw a similar distinction between tasks that require "codifiable" versus "tacit" information. Alan S. Blinder (2006) emphasizes, instead, the need for physical contact when delivering the output of a task. See also Pol Antràs, Luis Garicano, and Rossi-Hansberg (2006), who develop a theory in which the offshoring of certain types of tasks is an equilibrium outcome.

of their production to minimize costs. The equilibrium conditions determine the extent of offshoring in each industry, a continuous variable in our model.[3]

Our treatment of offshoring could be applied to a variety of settings with different numbers of goods and factors, production technologies, and market structures. To keep matters simple, we develop the model with at most two active industries, two or more factors of production, constant returns to scale, and perfectly competitive markets. We begin in Section I by allowing remote performance only of the tasks undertaken by low-skilled workers, while permitting such tasks to be conducted offshore in all industries. We introduce a parameter that describes the prospects for offshoring. Reductions in this parameter represent improvements in communication and transportation technology that reduce proportionally the cost of offshoring all tasks performed by low-skilled labor. With this parameterization, we can address an important and topical question, namely: how do improvements in the opportunities for offshoring affect the wages and well-being of different types of labor?

The rendering of a firm's geographic organization as a continuous variable permits a useful decomposition of the impact of an economy-wide decrease in offshoring costs on the wages of low-skilled workers. In general, a fall in the cost of separating low-skill tasks induces a *productivity effect*, a *relative-price effect*, and a *labor-supply effect* on low-skill wages. The productivity effect derives from the cost savings that firms enjoy when prospects for offshoring improve. This effect—which is present whenever the difficulty of offshoring varies by task, and task trade is already taking place—works to the benefit of low-skilled labor. A relative-price effect occurs when a fall in offshoring costs alters a country's terms of trade. The relative price of a good moves opposite to the change in its relative world supply. Such price movements are mirrored by movements in relative cost and have implications for wages that are familiar from traditional trade theories. Finally, the labor-supply effect operates in environments in which factor prices respond to factor supplies at given relative prices. This effect derives from the reabsorption of workers who formerly performed tasks that are now carried out abroad.

After developing our decomposition in Section II, we proceed to examine each of the effects in greater detail. Section IIA highlights the productivity effect by focusing on a small economy that produces two goods with two factors. In such an environment the terms of trade are fixed and wages do not respond to factor supplies, which leaves the productivity effect as the only remaining force. We show that improvements in the technology for offshoring low-skill tasks are isomorphic to (low-skilled) labor-augmenting technological progress and that, perhaps surprisingly, the real wage for low-skilled labor must *rise*. We contrast the effect of offshoring and immigration and argue that the latter will not result in a productivity effect.

In Section IIB and IIC, we introduce the relative-price effect and the labor-supply effect by analyzing first a large two-sector economy and then an economy in which the high-wage country specializes in the production of a single good. We show that the productivity effect is small when the range of offshored tasks is small, but it can outweigh the other effects when the volume of task trade is large. In Section III, we extend the model to include the possibility of offshoring tasks that require high-skilled labor. Here we identify another productivity effect, this one favoring high-skill workers.

Much has been written recently about offshoring. Part of this literature focuses on a firm's choice of organizational form.[4] Although this is an interesting problem, the models used to

[3] In this respect, our model resembles those in which goods are produced by a continuum of "stages of production," such as Avinash K. Dixit and Grossman (1982), Robert C. Feenstra and Hanson (1996), Yi (2003), and Wilhelm Kohler (2004b). However, none of these authors associates a production stage with a particular factor of production, and none allows heterogeneous trading costs or stages that can be separated from the partially processed good.

[4] See, for example, John E. McLaren (2000), Grossman and Helpman (2002, 2004, 2005), Antràs (2003), Dalia Marin and Thierry A. Verdier (2003a, 2003b), Antràs and Helpman (2004), and Antràs, Garicano, and Rossi-Hansberg (2006).

address it tend to be complex, incorporating imperfect information and subtle contracting or matching problems, and so the general equilibrium structure has been kept to a bare minimum. Another strand of literature, closer in spirit to this paper, models "fragmentation" of the production process. This has been conceived as the breakdown of technology for producing some good into discrete parts that can be separated in space.[5] The effects of such fragmentation hinge critically on the industry in which it occurs and the factor intensities of the fragments. A useful taxonomy has emerged, with a myriad of interesting possibilities, but general principles have been obscure. By treating offshoring as a continuous and ubiquitous phenomenon, we are able to synthesize this literature and lay bare its unifying principles. Another related literature examines globalization in models with tradeable intermediate inputs.[6] The distinction between "tasks" and "intermediate inputs" is largely semantic, but our incorporation of heterogeneous trade costs distinguishes our analysis from these earlier papers. The assumption of uniform (or zero) costs of trading intermediate goods has led the authors of these studies to overlook the positive productivity effect.

In sum, our paper makes two distinct contributions. First, it provides a simple and tractable model of offshoring that can be used for many purposes. By modeling the production process as a continuum of tasks, we are able to provide a novel decomposition of the effects of a fall in offshoring costs. Our second contribution is to uncover the productivity effect and to show that this effect is analogous to *factor-augmenting* technological change.[7] We characterize this effect fully and show that it typically grows with the volume of offshoring.

I. The Model

We conceptualize the production process in terms of tasks. Each task requires the input of some single factor of production. Some tasks can be performed by workers who have relatively little education or training, while others must be performed by workers who have greater skills. We refer to the former as "L-tasks" and the latter as "H-tasks." There may be still other tasks that are performed by other factors of production such as capital or additional categories of labor.

Firms in the home country can produce two goods, X and Y, with constant returns to scale. The production of a unit of either good involves a continuum of L-tasks, a continuum of H-tasks, and possibly other sets of tasks as well. Without loss of generality, we normalize the measure of tasks in each industry that employ a given factor of production to equal one. Moreover, we define the tasks so that, in any industry, those that can be performed by a given factor require similar amounts of that factor when performed at home. In other words, if L-tasks i and i' are undertaken at home in the course of producing good j, then firms use the same amount of domestic low-skilled labor to perform task i as they do to perform task i'.[8] The industries may differ in their factor intensities, which means, for example, that a typical L-task in one industry may use a greater input of domestic low-skilled labor than an L-task in the other industry.

[5] See, for example, Ronald W. Jones and Henryk Kierzkowski (1990, 2001), Alan V. Deardorff (2001a, 2001b), Hartmut Egger and Josef Falkinger (2003), and Kohler (2004a). Kohler (2004b) incorporates a continuum of fragments, but assumes uniform trading costs and allows fragmentation in only one industry.

[6] See, for example, Feenstra and Hanson (1996) and Yi (2003).

[7] Jones and Kierzkowski (1990, 2001), Sven W. Arndt (1997), Egger and Falkinger (2003), and Kohler (2004a, b) have recognized the analogy between fragmentation of the production process in some industry and technological progress in that same industry. Egger (2002) allows fragmentation in both sectors of a two-sector economy and points out the possibility of Pareto gains from an expansion of offshoring when the two sectors experience similar cost savings. These authors have not provided a natural framework to treat economy-wide offshoring and so have not drawn the connection we do between offshoring and factor-augmenting technological change.

[8] If one task needed to produce some good requires twice as much labor as another, we can always consider the former to be two tasks when assigning indexes to the tasks.

It is easiest to describe the production technology for the case in which substitution between the different tasks is impossible. We begin with this case and introduce the opportunities for offshoring. Then we return to the issue of task substitution and describe a more flexible technology.

If a production technology admits no substitution between factors or tasks, then each task must be performed at a fixed intensity in order to produce a unit of output. That is, each of the unit measures of L-tasks must be performed exactly "once" in order to produce a unit of output of good j, and similarly for each of the H-tasks and each of any other types of tasks that are part of the production process.[9] In industry j, a firm needs a_{fj} units of domestic factor f to perform a typical f-task once. Since the measure of f-tasks has been normalized to one for $f = \{L, H, \ldots\}$, a_{fj} also is the total amount of domestic factor f that would be needed to produce a unit of good j in the absence of any offshoring. We will take industry X to be relatively skill intensive, which means that $a_{Hx}/a_{Lx} > a_{Hy}/a_{Ly}$.

Firms can undertake tasks at home or abroad. Tasks can be performed offshore either within or beyond the boundaries of the firm. Much of the recent literature on offshoring distinguishes between firms that are vertically integrated and those that contract out for certain activities. There are many interesting questions about firms' choices of organizational form, but we shall neglect them here for the sake of simplicity. Rather, we assume that a firm needs the same amount of a foreign factor whether it performs a given activity in a foreign subsidiary or it outsources the activity to a foreign supplier. In either case, the factor requirement is dictated by the nature of the task and by the firm's production technology.

As we noted in the introduction, some tasks are more difficult to offshore than others. The cost of offshoring a task may reflect how difficult it is to describe using rules-based logic, how important it is that the task be delivered personally, how difficult it is to transmit or transport the output of the activity, or all of the above (and more). For our purposes, we simply need to recognize these differences, as we take the costs of offshoring the various tasks to be exogenous. For the time being, we focus sharply on the offshoring of tasks performed by low-skilled labor by assuming that it is prohibitively costly to separate all other tasks from the headquarters. We will examine the offshoring of high-skill tasks in Section III.

We index the L-tasks in an industry by $i \in [0, 1]$ and order them so that the costs of offshoring are nondecreasing. A simple way to model the offshoring costs is in terms of input requirements: a firm producing good j that performs task i abroad requires $a_{Lj}\beta t_j(i)$ units of foreign labor, where β is a shift parameter that we will use in Section II and beyond to study improvements in the technology for offshoring. We assume that $t_j(\cdot)$ is continuously differentiable and that $\beta t_j(i) \geq 1$ for all i and j. Our ordering of the tasks implies that $t_j'(i) \geq 0$. In the main text we will go further in taking this schedule to be strictly increasing, because this simplifies the exposition considerably. The appendix in Grossman and Rossi-Hansberg (2006) takes up the case in which the schedule has flat portions.[10]

Which industry finds it easier to move its L-tasks offshore? Note that this question is different from asking whether it is easier to offshore tasks performed by low-skilled workers or high-skilled workers. The two industries may share a set of common L-tasks—such as data entry, call center operations, and simple record-keeping and inventory control—for which the costs of offshoring are similar. Other tasks performed by low-skilled labor may differ across industries,

[9] We place quotation marks around "once," because there is no natural measure of the intensity of task performance.

[10] The $t_j(\cdot)$ schedule has a flat portion when a finite measure of tasks is equally costly to trade. On the one hand, this would seem possible in light of footnote 8, where we note that the "same" task may receive multiple indexes in order that all tasks use the same amount of a factor. On the other hand, if tasks are perfectly divisible into finer subtasks that are not exactly the same, then it may be plausible to assume that all finite measures of tasks bear slightly different offshoring costs.

but we know of no evidence to suggest that such tasks can more readily be moved offshore in labor-intensive sectors than in skill-intensive sectors (or vice versa). Indeed, improvements in transportation and communications technology have spurred the rapid growth of offshoring in a wide range of sectors. For this reason, we take as our benchmark the case in which offshoring costs are similar in the two industries, i.e., $t_x(i) = t_y(i) = t(i)$. But we will briefly address other possibilities in Section IIA.

We return now to the issue of factor and task substitution. Our framework can readily accommodate substitution between L-tasks and H-tasks (or tasks that use other factors) and substitution among the tasks that use a particular factor. But, to keep matters simple, we introduce only the former type of substitution in this paper.[11] The production technology may allow a firm to vary the intensities of L-tasks and H-tasks (and any other tasks) that it performs to produce a unit of output. For example, a firm might conduct the set of assembly (L) tasks repeatedly and oversight (H) tasks rarely, and thereby accept a relatively low average productivity of low-skilled labor, or it might conserve on assembly tasks by monitoring the low-skilled workers more intensively. The intensity of task performance is captured in our framework by the amount of the domestic factor that is used to perform a typical task at home. When substitution between L-tasks and H-tasks (and any others) is possible, a_{Lj} and a_{Hj} become choice variables for the firms, who select these variables to minimize cost subject to a constraint that the chosen combination of task intensities are sufficient to yield a unit of output. A firm that chooses a_{Lj} for the intensity of its L-tasks must employ $a_{Lj}\beta t(i)$ units of foreign labor to perform task i offshore.[12]

We are ready to describe an equilibrium with trade in goods and tasks. Let w and w^* be, respectively, the home and foreign wage of low-skilled workers, and suppose that $w > \beta t(0)w^*$, so that it is profitable for home firms to conduct some tasks abroad. Home firms offshore L -tasks in order to take advantage of the lower foreign wage, but they bear an administrative cost for doing so that varies with the nature of the job. In each industry, the marginal task performed at home has the same index I, which is determined by condition that the wage savings just balance the offshoring costs, or

$$w = \beta t(I)w^*. \tag{1}$$

In a competitive economy, the price of any good is less than or equal to the unit cost of production, with equality whenever a positive quantity of the good is produced. The unit cost of producing good j is the sum of the wages paid to domestic low-skilled labor, the wages paid to foreign labor for tasks performed offshore, the wages paid to domestic skilled labor for the unit measure of H-tasks, and the payments to any other factors of production. Considering firms' optimal choices of intensity a_{Lj}, a_{Hj}, etc., and the optimal offshoring of L-tasks, we have

$$p_j \leq wa_{Lj}(\cdot)(1 - I) + w^*a_{Lj}(\cdot)\int_0^I \beta t(i)\,di + sa_{Hj}(\cdot) + \ldots, \qquad \text{for } j = x, y, \tag{2}$$

where s denotes the high-skill wage, and the arguments in the function for the factor intensity a_{Fj} (which have been suppressed for the time being) are the relative costs of the various sets of tasks when they are located optimally. Notice that the wage bill for domestic low-skilled labor reflects the fraction $1 - I$ of L-tasks that are performed at home and that the wage bill for foreign

[11] Substitution among the tasks that use a particular factor could be introduced by assuming that such tasks generate an aggregate input that might, for example, be modeled as a constant-elasticity-of-substitution function of the intensity with which each task is performed. Qualitative results similar to those derived here will apply whenever the substitution among tasks using a given factor is less than perfect.

[12] Throughout the paper we assume that the characteristics of a given task do not vary depending on where the task is performed. Hence, foreign and local tasks of a given type are perfect substitutes in production.

low-skilled workers includes the costs of the "extra" inputs that are needed to do jobs from a distance; i.e., the costs of offshoring. The ellipses at the end of the inequality leave open the possibility that there are additional factors and additional tasks besides those performed by low-skilled and high-skilled labor.

By substituting for w^* using (1), we can rewrite (2) as

$$p_j \leq wa_{Lj}(\cdot)\Omega(I) + sa_{Hj}(\cdot) + \dots\ , \qquad \text{for } j = x, y, \tag{3}$$

where

$$\Omega(I) \equiv 1 - I + \frac{\int_0^I t(i)\,di}{t(I)}.$$

The first term on the right-hand side of (3) is the total cost of the unit measure of L-tasks in light of the profit-maximizing geographic allocation of these tasks. Notice that this cost is proportional to the chosen (or technologically fixed) intensity of task performance, with proportionality factor $w\Omega(I)$. Thus, $w\Omega(I)$ is the average cost of the low-skilled labor used to perform L-tasks, while s is the average cost of the skilled labor used to perform H-tasks. These average factor costs are the arguments in the $a_{fj}(\cdot)$ functions, because the tasks using a given factor are performed in fixed combination. Notice, too, that $t'(i) > 0$ for all $i \in [0,1]$ implies that $\Omega(I) < 1$ for $I > 0$; i.e., offshoring reduces the wage bill in proportion to the cost of performing all L-tasks at home, as long as some tasks are performed abroad.

Next consider the domestic factor markets. The market for low-skilled labor clears when employment by the two industries in the tasks performed at home exhausts the domestic factor supply, L. Each firm completes a fraction $1 - I$ of L-tasks at home, and an L-task in industry j employs a_{Lj} units of labor per unit of output. Letting x and y denote the outputs of the two industries, we have $(1 - I)a_{Lx}(\cdot)x + (1 - I)a_{Ly}(\cdot)y = L$, or

$$a_{Lx}(\cdot)x + a_{Ly}(\cdot)y = \frac{L}{1 - I}. \tag{4}$$

This way of writing the market-clearing condition highlights the fact that offshoring leverages the domestic factor supply; i.e., that an expansion in I is like an increase in L. For skilled labor, H, we have the usual

$$a_{Hx}(\cdot)x + a_{Hy}(\cdot)y = H, \tag{5}$$

because we are assuming for the time being that tasks requiring skilled labor cannot be performed remotely. Conditions analogous to (5) apply for any additional factors that may take part in the production process.[13]

Lastly, we have the markets for consumer goods. We assume as usual that households have identical and homothetic preferences around the globe and take good X as numeraire. If the home country is small in relation to the size of world markets, the relative price p can be treated

[13] We assume that factor markets are competitive so firms have no monopsony power. We might alternatively assume that firms can keep some of the benefits that result from a reduction in offshoring costs by using their monopsony power in factor markets. Similarly, we might assume that a reduction in offshoring costs enhances firms' market power. Then there would be an additional channel through which offshoring could affect wages. To keep our analysis as simple as possible, however, we maintain the assumption of competitive markets throughout the paper.

as exogenous by the domestic economy. If the home country is large, the relative price is determined by an equation of world relative demands and world relative supplies. We shall refrain from writing this equation explicitly until we need it in Section IIB below.

II. Decomposing the Wage Effects of Offshoring

The Internet allows nearly instantaneous transmission of information and documents. Cellular telephones connect remote locations that have limited access to land lines. Teleconferencing provides an ever closer approximation of face-to-face contact. These innovations and more have dramatically reduced the cost of offshoring. We model such technological improvements as a decline in β and use comparative-static methods to examine their effects.

In this paper, we are most interested in the effects of offshoring on domestic factor prices. Before proceeding to particular trading environments, we identify the various channels through which changes in the opportunities for offshoring affect the wages of low-skilled and high-skilled labor. Our decomposition results from differentiating the system of zero-profit and factor-market clearing conditions and taking Ω, p, and I as exogenous variables for the moment. Of course, these variables are endogenous to the full equilibrium, and we shall treat them as such in the subsequent analysis.

When both industries are active, the pair of zero-profit conditions in (3) hold as equalities. These two equations, together with the factor-market clearing conditions that apply for all of the inelastically supplied factors, allow us to express the vector of domestic factor prices and the two output levels as functions of p, I, and Ω. After totally differentiating this system of $2 + v$ equations (where v is the number of factors), we can write the expression for the (proportional) change in the wage of low-skilled labor as

$$\hat{w} = -\hat{\Omega} + \mu_1 \hat{p} - \mu_2 \frac{dI}{1-I}, \tag{6}$$

where the μ_i's collect all the terms that multiply dp/p and $dI/(1-I)$, respectively.

We call the first term on the right-hand side of (6) the *productivity effect*. As the technology for offshoring improves ($d\beta < 0$), the cost of performing the set of L-tasks declines in both industries ($\hat{\Omega} < 0$).[14] A firm's cost savings are proportional to its payments to low-skilled labor. These savings are much the same as would result from an economy-wide increase in the productivity of low-skilled labor, hence the term we have chosen to describe the effect. The boost in productivity raises firms' demand for low-skilled labor, which tends to inflate their wages, much as would labor-augmenting technological progress.

The second term on the right-hand side of (6) is the *relative-price effect*. A change in the ease of offshoring often will alter the equilibrium terms of trade. If the relative price of the labor-intensive good Y falls, this typically will exert downward pressure on the low-skill wage via the mechanism that is familiar from Wolfgang F. Stolper and Paul A. Samuelson (1941). Since improvements in the technology for offshoring generate greater cost savings in labor-intensive industries than in skill-intensive industries, ceteris paribus, a fall in β often will induce a fall in

[14] Strictly speaking, this is true only when $I > 0$ in the initial equilibrium. Note that $dI/d\beta < 0$ (as we will argue below) and

$$\frac{d\Omega}{dI} = \frac{-\int_0^I t(i)\,di}{[t(I)]^2} t'(I),$$

which is zero when $I = 0$ and negative when $I > 0$.

the relative price of the labor-intensive good ($\hat{p} < 0$). Hence, the relative-price effect typically works to the disadvantage of low-skilled labor, as we will see in Section IIB.

We refer to the final term in (6) as the *labor-supply effect.* As technological improvements in communication and transportation cause the offshoring of L-tasks to expand, ($dI > 0$), this frees up domestic low-skilled labor that otherwise would perform these tasks. These workers must be reabsorbed into the labor market, which may (but need not) contribute to a decline in their wages. We see in equation (4) that the domestic economy operates as if it had a labor supply of $L/(1-I)$, which means that an expansion of offshoring of $dI/(1-I)$ increases the effective supply of low-skilled labor by a similar amount as would a given percentage growth in the domestic labor supply L.

We can also decompose the effects of a decline in the costs of offshoring L-tasks on the income of high-skilled labor. Analogous to (6), we find

$$\hat{s} = -\mu_3 \hat{p} + \mu_4 \frac{dI}{1-I}. \tag{7}$$

Notice that there is no productivity effect. This is because a fall in β reduces firms' costs of performing their L-tasks, without any direct effect on the cost of performing tasks that require high-skilled labor. Thus, there is no *direct* boost to productivity of these skilled workers, although there may be indirect effects that result from changes in factor proportions and changes in relative prices. We write the relative-price effect with the opposite sign to that in (6), because, at least in a two-factor model, a movement in relative prices pushes the two factor prices in opposite directions. Similarly, we write the labor-supply effect with a positive sign. Often, an increase in the effective supply of low-skilled labor such as the one that results from increased offshoring will raise the low-skill to high-skill employment ratios in the various industries, thereby increasing the marginal product of skilled labor. However, as we know from standard analyses of the Heckscher-Ohlin model, a change in relative factor supplies may be accommodated by a change in the composition of output, without any response of factor proportions in any industry. In such circumstances, we will have $\mu_2 = \mu_4 = 0$.

We turn now to some specific trading environments, where these effects can be isolated and understood more fully. In so doing, we study a full equilibrium in which all relevant variables are treated as endogenous.

A. *The Productivity Effect*

The productivity effect may seem counterintuitive, because it works to the benefit of the factor whose tasks are being moved offshore. But it arises quite generally in all trading environments in which the volume of offshoring is already positive and the cost of offshoring falls.[15] We devote this section to studying it in some detail.

The productivity effects are seen most clearly in a small Heckscher-Ohlin economy. Consider an economy that takes the relative price p and the foreign wage w^* as given and that produces output with only two factors, L and H. As before, output requires unit measures of L-tasks and H-tasks, and only the former tasks can be moved offshore at reasonable cost.

[15] Feenstra and Hanson (1996) study an expansion in offshoring that is precipitated by growth in the capital stock of the low-wage country. Since they assume that offshoring is costless, their analysis neglects the productivity effect that we have identified here.

Assuming that both industries are active in equilibrium, the zero-profit conditions imply[16]

$$1 = \Omega w a_{Lx}(\Omega w/s) + s a_{Hx}(\Omega w/s) \tag{8}$$

and

$$p = \Omega w a_{Ly}(\Omega w/s) + s a_{Hy}(\Omega w/s). \tag{9}$$

Here, we have made explicit the dependence of the production techniques on the relative average factor costs, $\Omega w/s$, in view of the profit-maximizing choice of offshoring dictated by (1). Since the industries differ in factor intensities, these two equations uniquely determine Ωw and s, independently of β. Thus, as β falls, $\hat{w} = -\hat{\Omega}$ and $\hat{s} = 0$. We conclude that the productivity effect is the *only* effect that operates in the present setting.[17] The relative-price effects are absent ($\mu_1 = \mu_3 = 0$), because terms of trade are exogenous in a small economy. The labor-supply effects are absent ($\mu_2 = \mu_4 = 0$), because factor prices are insensitive to factor supplies (at given commodity prices) in an economy with equal numbers of primary factors and produced goods.

We can compute the magnitude of the productivity effect by combining $\hat{w} = -\hat{\Omega}(I)$ and $\hat{w} = \hat{\beta} + \hat{t}(I)$, which follows from (1) and the fact that w^* is fixed for a small country. Solving this pair of equations gives

$$\hat{w} = -\hat{\Omega} = -\frac{\int_0^I t(i)\, di}{(1 - I)t(I)}\hat{\beta}.$$

We see that the productivity effect is zero when $I = 0$, but strictly positive for all $I > 0$. Thus, low-skilled labor benefits from improvements in the technology for offshoring L-tasks whenever some task trade already occurs. Moreover, the wage gain from a given percentage reduction in offshoring costs increases monotonically with I if $\eta(i) \equiv t'(i)(1 - i)/t(i) < 1$ for all i, or if $\eta(i)$ is constant (i.e., $t(i) = (1 - i)^{-\eta}$). When one of these conditions is satisfied, it guarantees that the costs of offshoring do not rise "too" fast with i. Then $\partial\hat{\Omega}/\partial I < 0$ and $\partial\hat{w}/\partial I > 0$.

How can low-skilled workers benefit when it becomes easier to move the tasks they perform offshore? To answer this question, consider the cost savings generated by an improvement in the technology for offshoring. Firms' costs fall for two reasons. First, the firms elect to relocate tasks that previously were carried out at home. Second, firms save on inframarginal tasks that were conducted abroad even before the drop in β. The envelope theorem implies that the first source of savings is negligible for a small change in β. But the second source of savings is of the first order, provided that there exist some inframarginal tasks (i.e., $I > 0$). The sectoral composition of these cost savings explains the ultimate gain by domestic, low-skilled labor.

Firms in both industries benefit at the initial factor prices from the reduction in β. But the increase in profitability is greater in the labor-intensive sector than in the skill-intensive sector, because a firm's savings are proportional to the share of L-tasks in its total costs. Therefore, the

[16] To simplify notation, we suppress the arguments of functions whenever this dependence is clear from the context (e.g., we write Ω instead of $\Omega(I)$).

[17] The exercise we are undertaking here is somewhat artificial inasmuch as we consider a change in technology that reduces the cost of offshoring in a single, small economy while holding goods prices and foreign wages fixed. This situation can arise only when the costs of offshoring do not also change in other countries that in aggregate are large. Such a scenario would not be an apt description of the recent boom in offshoring triggered by the information technology revolution. Paul R. Krugman (2000) makes a similar point in his critique of Leamer's (1998, 2000) small-country analysis of the effects of factor-biased technological change on factor prices. We intend the small-country analysis only as a pedagogic device that lays bare the source of the productivity effect, not as a realistic description of the recent experience with offshoring of any small, industrialized country.

labor-intensive industry enjoys the greater increase in profitability at the initial factor prices. As it expands relative to the skill-intensive sector, the economy-wide demand for low-skilled labor grows. Only when the domestic wage rises to fully offset the induced increase in productivity can the profit opportunities in both industries simultaneously be eliminated. In the process, the wage of high-skilled labor is left unchanged. Again, we see the strong analogy between improved opportunities for offshoring and labor-augmenting technological progress.

It is instructive to compare the incidence of a decline in the cost of offshoring with that of a fall in the cost of immigration. Both generate an expansion in the pool of labor available to perform L-tasks and both spell an increase in the fraction of these tasks that are performed by foreign-born labor. Yet, we would argue, the implications for domestic wages are very different. Suppose, for the sake of this comparison, that foreign workers can stay in their (large) native country and earn the wage w^*, or they can move to the home country at the cost of a fraction of their working time. Let this cost vary across individuals, so that potential immigrant i captures only the fraction $1/\beta\tau(i)$ of the domestic wage w when he moves to the high-wage country. Assume that foreign workers employed in the home country are equally productive with their domestic counterparts. Then, the marginal immigrant I earns the same net income in both locations, or $w = w^*\beta\tau(I)$. Note the similarity with equation (1). However, unless the domestic firms know the immigrants' moving costs and can price discriminate in their wage offers, they will pay the same wage w to all low-skilled immigrant workers, as well as to all such domestic workers. As the cost of immigration falls, rents accrue to the immigrants, *but not to the domestic firms*. Hence, there is no increase in profitability and no pressure for domestic wages to change (as long as the economy remains incompletely specialized). The difference between falling costs of offshoring and falling costs of immigration is that the former create rents for domestic firms—which ultimately accrue to domestic factors in the general equilibrium—whereas the latter create rents for the immigrants.

Until now, we have assumed that the distribution of offshoring costs by task is the same in both industries. What if they are different? Suppose first that it is possible to offshore tasks only in the labor-intensive industry and that the technology for offshoring these tasks improves. This is like labor-augmenting technological progress concentrated in industry Y. The wage of low-skilled workers will rise by more than the percentage fall in Ω_y, and the wage of high-skilled workers will fall.[18] In contrast, if the offshoring of L-tasks is possible only in the skill-intensive industry, then an improvement in the technology for offshoring will raise the wage of high-skilled labor and reduce that of low-skilled labor. These scenarios are quite similar to those analyzed by Jones and Kierzkowski (2001), where they considered the effects of fragmentation of the production process in a single industry. They showed that technological improvements that make it possible to import a component that formerly had to be produced at home are like productivity gains in the industry where this occurs. They also noted the analogy of such fragmentation with industry-specific technological progress, which, in a small country, benefits the factor that is used intensively in the industry that reaps the productivity gains. The main difference between their result and ours is that they identify a productivity gain for the industry in which fragmentation occurs,

[18] We define $\Omega_y \equiv 1 - I_y + \int_0^{I_y} t_y(i)\, di/t_y(I_y)$, where I_y is the fraction of tasks performed offshore in industry Y. It is straightforward to calculate that

$$\hat{w} = -\hat{\Omega}_y\left(\frac{\theta_{Hx}\theta_{Ly}}{\theta_{Hx}\theta_{Ly} - \theta_{Lx}\theta_{Hy}}\right) > -\hat{\Omega}_y \geq 0$$

and

$$\hat{s} = -\frac{\theta_{Lx}}{\theta_{Hx}}\hat{w} < 0,$$

where θ_{fj} is the cost share of f-tasks in industry j.

whereas we associate the productivity gain with the factor performing tasks that become cheaper to trade. When offshoring costs fall for one factor and in one industry, the implications of the alternative approaches converge.[19]

More generally, we can write the wage response to a change in the ease of offshoring that affects the two industries differently as

$$\hat{w} = \frac{\frac{\theta_{Hx}}{\theta_{Lx}}(-\hat{\Omega}_y) - \frac{\theta_{Hy}}{\theta_{Ly}}(-\hat{\Omega}_x)}{\frac{\theta_{Hx}}{\theta_{Lx}} - \frac{\theta_{Hy}}{\theta_{Ly}}},$$

where Ω_x is defined analogously to Ω_y. In the numerator, the productivity gain in the labor-intensive industry Y is weighted by the factor-share ratio, θ_{Hx}/θ_{Lx}, which exceeds the weight θ_{Hy}/θ_{Ly} on the productivity gain in the skill-intensive industry. The denominator is always positive. Therefore, the low-skill wage rate will rise if the productivity gains are similar in the two industries, or if that in the labor-intensive sector is larger. The link between a decline in the cost of task trade and the relative sizes of the productivity gains in the two industries is, however, not obvious when the industries have different trade cost schedules. Take, for example, the case in which $t_x(i) = \alpha t_y(i)$ and both schedules are multiplied by a common factor β. Then, as β falls, the cost of offshoring the task with index i falls by the same percentage amount in both industries (so $\hat{\Omega}_x(i) = \hat{\Omega}_y(i)$ all i), but since the industries do not offshore the same fractions of tasks, the productivity gains are not the same. In fact, the industry in which task trade is less costly offshores a larger fraction of tasks; i.e., $I_x > I_y$ if and only if $\alpha < 1$. But this alone does not guarantee a larger productivity gain for the industry with the lower cost of offshoring. We define $\eta_j(i) \equiv t_j'(i)(1 - i)/t_j(i)$ for $i = x, y$, analogous to our definition of $\eta(i)$ above. Then, if η_x and η_y are constants, or if $\eta_x(I_x) < 1$ and $\eta_y(I_y) < 1, \hat{\Omega}_j(i)$ is increasing in i and the industry with the greater ease of offshoring will experience the larger productivity gain when β falls.

Turning to the high-skill wage, we find

$$\hat{s} = \frac{\theta_{Ly}\theta_{Lx}}{\theta_{Ly} - \theta_{Lx}}\left[(-\hat{\Omega}_x) - (-\hat{\Omega}_y)\right].$$

Since $\theta_{Ly} > \theta_{Lx}$, skilled labor benefits from a fall in offshoring costs in a small country if and only if the induced productivity gain in the skill-intensive sector exceeds that in the labor-intensive sector.

B. *The Relative-Price Effect*

To examine the relative-price effect, we relax the small-country assumption. Now we need equilibrium conditions for the foreign country and a reason why factor prices differ across countries. To this end, we assume that indigenous firms in the foreign country use inferior technologies. The technology gap generates factor prices that are lower in the foreign country than those in the home country. Since all task trade is costly, only the firms in the technologically

[19] See also Leamer (1998, 2000), who emphasizes that the factor bias of technological progress has no bearing on the implications for factor prices in a small open economy. Rather, what matters for the wage response is the sector in which the technological progress takes place. But note Krugman's (2000) critique of the small-economy assumption in the context of *global* technological change, as discussed in footnote 17.

advanced country engage in offshoring. We return to our benchmark case in which the offshoring of L-tasks has the same distribution of costs in the two industries.

More specifically, we let $A^* > 1$ denote the Hicks-neutral technological inferiority of foreign firms in both industries. This means that, were a foreign firm to perform all tasks at the same intensities as a domestic firm, its output would be only $1/A^*$ times as great. Assuming incomplete specialization in the foreign country, the zero-profit conditions for indigenous foreign firms imply

$$1 = A^* w^* a_{Lx}(w^*/s^*) + A^* s^* a_{Hx}(w^*/s^*) \tag{10}$$

and

$$p = A^* w^* a_{Ly}(w^*/s^*) + A^* s^* a_{Hy}(w^*/s^*). \tag{11}$$

Comparing (8) and (9) with (10) and (11), we see that incomplete specialization in both countries implies "adjusted factor price equalization"; that is, $w\Omega = w^* A^*$ and $s = s^* A^*$.

In such an equilibrium, home firms choose their production techniques based on the relative average factor costs $w\Omega/s$. Foreign firms choose theirs based on the relative factor prices w^*/s^*. Therefore, with adjusted factor price equalization, the relative cost-minimizing techniques are the same in the two countries, i.e., $a_{fj} A^* = a^*_{fj}$. The foreign factor-market clearing conditions can be written as

$$A^* a_{Lx} x^* + A^* a_{Ly} y^* + \beta \int_0^I t(i)\, di\, (a_{Lx} x + a_{Ly} y) = L^*$$

and

$$A^* a_{Hx} x^* + A^* a_{Hy} y^* = H^*,$$

where x^* and y^* are the industry outputs of indigenous foreign firms in industries X and Y, and L^* and H^* are the foreign endowments of low-skilled and high-skilled labor. Here, the demand for foreign low-skilled labor comprises three terms: the demand by indigenous foreign firms in industry X, the demand by indigenous foreign firms in industry Y, and the demand by home firms in both industries that are offshoring the set of L-tasks with indexes $i \leq I$. The demand for foreign high-skilled labor comprises only the demands of the two foreign industries, because the offshoring of H-tasks still is assumed to be impossible.

Now, we combine the factor-market clearing conditions for the foreign country with those for the home country to derive expressions for the world outputs of the two goods. We find[20]

[20] As an intermediate step, we note that

$$a_{Lx} x^* + a_{Ly} y^* = \frac{L^*}{A^*} - \frac{\beta}{(1-I)A^*} \left[\int_0^I t(i)\, di \right] L$$

and

$$a_{Hx} x^* + a_{Hy} y^* = \frac{H^*}{A^*}.$$

Now, we can solve for x^* and y^*, and similarly for x and y, and sum the home and foreign outputs of a good to arrive at the expressions in the text.

$$x + x^* = \frac{a_{Ly}\left(H + \frac{H^*}{A^*}\right) - a_{Hy}\left(\frac{L^*}{A^*} + \frac{L}{\Omega}\right)}{\Delta_a} \tag{12}$$

and

$$y + y^* = \frac{a_{Hx}\left(\frac{L^*}{A^*} + \frac{L}{\Omega}\right) - a_{Lx}\left(H + \frac{H^*}{A^*}\right)}{\Delta_a}, \tag{13}$$

where $\Delta_a = a_{Hx}a_{Ly} - a_{Lx}a_{Hy} > 0$.

Equilibrium in the goods market requires

$$\frac{y + y^*}{x + x^*} = D(p),$$

where $D(p)$ is the (homothetic) world relative demand for good Y, which has the standard property that $D'(p) < 0$.

The expressions for world outputs have some interesting implications. First, note that $w\Omega = w^*A^*$ and $w = \beta t(I) w^*$ together imply

$$A^* = \beta t(I)\Omega(I) = \beta\left[(1 - I)t(I) + \int_0^I t(i)\,di\right].$$

Therefore, when the cost of offshoring falls ($d\beta < 0$), home firms broaden the range of tasks that they perform offshore ($dI > 0$).[21] This reduces the cost of L-tasks for these firms ($\hat{\Omega} < 0$), the more so for labor-intensive producers than for skill-intensive producers. Equations (12) and (13) imply that, as Ω falls, the relative world output of labor-intensive goods must rise. Finally, since $(y + y^*)/(x+x^*)$ increases and $D'(p) < 0$, the relative price of the labor-intensive good falls ($\hat{p} < 0$).

The relative-price effect rewards high-skilled labor but harms low-skilled labor, for the usual (Stolper-Samuelson) reasons. Given the relative price p, in an incompletely specialized, Heckscher-Ohlin economy, there are no labor-supply effects ($\mu_2 = \mu_4 = 0$), because changes in factor supplies induce changes in the composition of output, not changes in factor intensities. It follows that domestic high-skilled labor must gain from an improvement in the technology for offshoring. Domestic low-skilled labor may gain or lose, depending on the relative sizes of the productivity and relative-price effects and on the share of the labor-intensive good in the typical consumption basket.[22] Note that a fall in the cost of task trade can generate a Pareto improvement for the home country if the productivity effect is large enough. This is quite different from the consequences of a fall in the cost of goods trade, which necessarily creates winners and losers.

[21] Note that

$$\frac{d\left[(1 - I)t(I) + \int_0^I t(i)\,di\right]}{dI} = (1 - I)t'(I) > 0.$$

[22] The real wage of low-skill labor can rise even if w (measured in terms of the numeraire good X) falls, because a fall in β induces a decline in the price of good Y. Note, too, that the effect of globalization on wages need not be monotonic, in contrast to a world with only goods trade. Therefore, Krugman's (2000) argument that the impact of trade on wages is largest when the volume of trade is large need not apply here.

We highlight one further implication of equations (12) and (13). Notice that the domestic labor supply enters these expressions for the global outputs only in the form L/Ω. Thus, $1/\Omega$ acts as a productivity level that multiplies labor units to convert them into "efficiency" units of labor. As should be clear, the analogy between reductions in the cost of offshoring and labor-augmenting technological progress carries over to the large economy. A decline in β that induces an expansion of task trade and thus a fall in Ω has exactly the same impact on prices, wages, and world outputs as an enhancement in the productivity of domestic low-skilled labor in all of its uses.

C. *The Labor-Supply Effect*

We have seen that increased offshoring of the tasks performed by low-skilled labor acts, in part, like an expansion of the domestic labor supply. As more tasks are moved offshore, domestic low-skilled workers are freed from their jobs and so must find new tasks to perform elsewhere in the economy. Yet, the labor-supply effect on wages has been absent from the trading environments we have considered so far, because factor prices are insensitive to factor supplies in an economy that produces as many tradable goods as there are primary factors.

The labor-supply effect operates in any setting with more factors than produced goods. It would be present, for example, in a small economy that produces two goods with three factors, such as in the familiar specific-factors model. It also operates in a world economy with many goods and two factors in which two large countries produce only one good in common. This is the setting studied by Feenstra and Hanson (1996), and the labor-supply effect features prominently in their analysis. We can elucidate this effect more clearly, however, in an even simpler environment. To this end, we consider a small economy as in Section IIB that takes the foreign wage and relative price as given, but one that is specialized in producing a single good.

Suppose the home country produces only the numeraire good X. Then the zero-profit condition for this industry implies that equation (8) must hold, whereas the price p is less than the unit cost of production in industry Y. The factor-market clearing conditions are quite simple in this setting, and they require

$$a_{Lx}(w\Omega/s)x = \frac{L}{1-I}, \tag{14}$$

and

$$a_{Hx}(w\Omega/s)x = H. \tag{15}$$

Consider a decline in the cost of trading tasks ($d\beta < 0$). Differentiating (8) gives

$$\theta_{Lx}(\hat{w} + \hat{\Omega}) + (1 - \theta_{Lx})\hat{s} = 0,$$

while differentiating the ratio of (14) to (15) implies

$$\sigma_x(\hat{s} - \hat{w} - \hat{\Omega}) = \frac{dI}{1-I},$$

where σ_x is the elasticity of substitution between the set of L-tasks and the set of H-tasks in the production of good X. Combining these two equations, we find that

$$\hat{w} = -\hat{\Omega} - \frac{1-\theta_{Lx}}{\sigma_x}\frac{dI}{1-I}. \tag{16}$$

The first term on the right-hand side of (16) is the productivity effect, as before. The second term is the labor-supply effect on low-skilled wages. The former effect is positive, while the latter is negative and reflects the adjustment in wages necessary for all domestic low-skilled workers to be employed when performing the smaller set of tasks undertaken in the home country.

To compare the magnitudes of these offsetting effects, we need to relate $-\hat{\Omega}$ to $dI/(1-I)$. This can easily be done using the definition of $\Omega(I)$ or the derivative $d\Omega/dI$ reported in footnote 14. We find that $-\hat{\Omega} = \eta\gamma dI/(1-I)$, and so

$$\hat{w} = \left[\eta\gamma - \frac{1-\theta_{Lx}}{\sigma_x}\right]\frac{dI}{1-I}$$

where, as before,

$$\eta(I) \equiv \frac{t'(I)(1-I)}{t(I)}$$

is the elasticity of the trade cost schedule when expressed as a function of $1-I$, and

$$\gamma(I) \equiv \frac{\int_0^I t(i)\,di}{\int_0^I t(i)\,di + (1-I)t(I)}$$

is a fraction that is zero at $I=0$ and one at $I=1$. The productivity effect is negligible when $I=0$ but can be large when $I>0$ and the cost schedule for trading tasks rises steeply. The labor-supply effect is large when the share of skilled labor in total costs is large and when H-tasks substitute poorly for L-tasks in the production process. Clearly, the labor-supply effect dominates when $I=0$, which means that the first bit of offshoring drives down the wages of domestic low-skilled workers. This is because the productivity effect rests on the cost-savings for inframarginal tasks, and there are no such tasks when the complete production process is performed initially at home. However, reductions in the cost of task trade that cause offshoring to grow from an already positive level can produce an increase in low-skill wages despite the existence of an adverse labor-supply effect. We see that, when $I>0$, a fall in β causes w to rise if and only if $\sigma_x\gamma\eta > 1-\theta_{Lx}$. Moreover, for some production and offshoring technologies, a sufficiently large fall in the costs of offshoring will leave low-skilled labor with higher real wages than they would have with no offshoring, despite the initial drop in wages that results from a small increase in offshoring when $I=0$.[23]

The labor-supply effect that may harm low-skilled workers serves to benefit their high-skilled compatriots. The high-skilled domestic workers experience no direct productivity effect, but they enjoy a boost to their marginal product when offshoring becomes less costly, because the expansion in task trade generates an increase in the intensity with which every L-task is performed. We find that

[23] For example, if the technology for producing good X is Cobb-Douglas, the foreign wage w^* is sufficiently low, and $\lim_{i\to 1} t'(i)/t(i) = \infty$, then the equilibrium domestic wage of low-skilled workers is higher for β sufficiently low (and, therefore, $I>0$) than when $I=0$.

$$\hat{s} = \frac{\theta_{Lx}}{\sigma_x}\frac{dI}{1 - I},$$

which is positive for all I. Thus, with more factors than goods, skilled-labor always gains when the cost of offshoring L-tasks falls.

III. Offshoring Skill-Intensive Tasks

Much of the recent public debate about offshoring concerns the relocation of white-collar jobs. The media has identified many tasks requiring reasonably high levels of skill that formerly were the sole providence of the advanced economies but now are being performed offshore on behalf of consumers in advanced economies. For example, workers in India are reported to be reading x-rays,[24] developing software,[25] preparing tax forms (Jesse Robertson et al. 2005), and even performing heart surgery on US patients.[26] In this section, we extend our model to include trade in such tasks.

We introduce the possibility of offshoring tasks performed by high-skilled workers in the setting of a small Heckscher-Ohlin economy. Let $\beta_f t_f(i)$ denote the ratio of the input of foreign factor f needed to perform the f-task with index i at a given intensity to the domestic input of factor f needed to perform the same task at the same intensity, for $f = \{L, H\}$. We assume that the two industries share the same schedules of offshoring costs, although it would be straightforward to allow for cross-sectoral variation in these costs, as we have illustrated before.

Now, I_f is the marginal task using factor f that is performed offshore. For low-skilled labor, we have

$$w = w^* \beta_L t_L(I_L), \tag{17}$$

as before. The analogous condition for high-skilled labor is

$$s = s^* \beta_H t_H(I_H). \tag{18}$$

If home firms produce both goods, the zero-profit conditions imply

$$1 = \Omega_L w a_{Lx}(\Omega_L w/\Omega_H s) + \Omega_H s a_{Hx}(\Omega_L w/\Omega_H s) \tag{19}$$

and

$$p = \Omega_L w a_{Ly}(\Omega_L w/\Omega_H s) + \Omega_H s a_{Hy}(\Omega_L w/\Omega_H s), \tag{20}$$

where

$$\Omega_f(I_f) \equiv 1 - I_f + \frac{\int_0^{I_f} t_f(i)\, di}{t_f(I_f)}$$

[24] Andrew Pollack, "Who's Reading Your X-Ray?" *New York Times*, November 16, 2003.

[25] Scott Thurm, "Tough Shift — Lesson in India: Not Every Job Translates Overseas." *New York Times*, March 3, 2004.

[26] Unmesh Baker, Simon Montlake, Hilary Hylton, Chris Daniels, and Jenn Holmes. "Outsourcing Your Heart Elective Surgery in India? Medical Tourism is Booming, and US Companies Trying to Contain Health-Care Costs Are Starting to Take Notice." *Time*, May 29, 2006.

for $f = \{L, H\}$. Together, (17)–(20) determine w, s, I_L, and I_H, given w^*, s^*, and p, which the small country takes as given.

But, in fact, (19) and (20) determine $\Omega_L w$ and $\Omega_H s$ independently of β_L and β_H. Therefore, as long as the country remains incompletely specialized, a fall in the cost of offshoring one or both types of task leaves $\Omega_L w$ and $\Omega_H s$ unchanged. It follows that

$$\hat{w} = -\hat{\Omega}_L$$

and

$$\hat{s} = -\hat{\Omega}_H,$$

with $d\Omega_L/d\beta_L > 0$, $d\Omega_H/d\beta_L = 0$, $d\Omega_H/d\beta_H > 0$, and $d\Omega_L/d\beta_H = 0$. That is, an improvement in the technology for offshoring L-tasks generates as before a productivity gain for low-skilled workers and a rise in their wages, but has no effect on the extent of offshoring of H-tasks or the wages of high-skilled workers. Similarly, a reduction in the cost of offshoring high-skilled jobs spurs additional offshoring of H-tasks, with attendant productivity gains for domestic high-skilled workers and an increase in their wages. Such changes in communication and transportation technologies do not affect the allocation of low-skilled tasks or the wages of low-skilled workers in this setting.

We can also analyze the offshoring of H-tasks in a large economy or one that is specialized in producing a single good. In the large economy, a fall in β_H alone generates a relative-price effect that benefits low-skilled labor and harms high-skilled labor. In the specialized economy, such technological change induces a factor-supply effect that has these same distributional consequences.

An interesting special case arises when the distribution of trading costs for H-tasks is the same for L-tasks, and improvements in communications technology shift both schedules down symmetrically, i.e., $t_L(\cdot) = t_H(\cdot) = t(\cdot)$ and $\beta_L = \beta_H = \beta$. Suppose the home country is large, as in Section IIB, and that it enjoys an economy-wide productivity advantage vis-à-vis its trading partner, as captured by $A^* > 1$. Then, if both countries are incompletely specialized, adjusted factor price equalization implies $\Omega_L w = A^* w^*$ and $\Omega_H s = A^* s^*$, where $\Omega_L = \Omega(I_L)$ and $\Omega_H = \Omega(I_H)$. We can substitute for w^* using (17) and for s^* using (18), which gives $\beta t(I_L)\Omega(I_L) = A^* = \beta t(I_H)\Omega(I_H)$, or $I_L = I_H$. That is, the extent of equilibrium offshoring is the same for the two types of tasks.[27]

When trade costs fall, the fraction of tasks of each type that is performed offshore increases to the same extent. Then, $-\hat{\Omega}_L = -\hat{\Omega}_H > 0$; i.e., both factors enjoy similar productivity gains. The reduction in offshoring costs is like uniform factor-augmenting technological progress, or, equivalently, uniform Hicks-neutral technological progress in both industries. However, this does not generate uniform growth in factor prices. Rather, the uniform expansion in productivity in the (skill-abundant) home economy causes an expansion in relative world output of the skill-intensive good at the initial world price and thus a deterioration in the home country's terms of trade. The induced rise in p produces a relative-price effect that further boosts the wage gain for low-skilled labor, but mitigates (or, possibly, reverses) that for their high-skilled counterparts.

[27] Note that $\beta_L = \beta_H$ and $t_L(\cdot) = t_H(\cdot)$ are not enough to ensure that an economy offshores the same fraction of L-tasks as H-tasks, because the relative cost of one factor may be higher or lower in the foreign country than in the home country when $I_L = I_H$. So, for example, firms in a small economy typically will not offshore L-tasks and H-tasks to the same extent even when the distributions of offshoring costs are the same, unless w^*/s^* takes on a particular value. But, with uniform productivity differences across a pair of large countries and adjusted factor price equalization, the relative factor prices in both countries are in fact the same when $I_L = I_H$.

IV. Conclusion

The nature of trade has changed dramatically over the last two centuries. Whereas trade historically has involved an exchange of complete goods, today it increasingly entails different countries adding value to global supply chains. We have introduced the term "task trade" to describe this finer international division of labor and to distinguish it from goods trade, with its coarser patterns of specialization. Although the globalization of production has been discussed extensively in formal and informal writings, there is no basic framework to study this new international organization of supply and its consequences for prices, resource allocation, and welfare. In this paper, we have proposed such a model that casts task trade as star while relegating goods trade to a supporting role.

Our shifted emphasis generates insights that are surprising from the perspective of traditional theories in which only goods are traded. In particular, we have identified a productivity effect that results from improvements in the technology for trading tasks. A decline in the cost of task trade has effects much like factor-augmenting technological progress. That is, it directly boosts the productivity of the factor whose tasks become easier to move offshore. If the ensuing adjustment in relative prices is not too large or its impact on factor prices is not too powerful, all domestic parties can share in the gains from improved opportunities for offshoring. In contrast, several familiar trade theories predict an inevitable conflict of interests when the cost of trading goods falls.

Our conceptualization of the global production process in terms of tradeable tasks yields dividends in a parsimonious analysis of the distributional implications of offshoring. Of course, in developing our specific model of task trade, we have imposed several restrictions on the available production and trade technologies. We believe that two of these restrictions are especially important and hope to relax them in future research. First, our specific production technology limits the potential patterns of complementarity between tasks. We have allowed for any degree of substitution or complementarity between the set of tasks performed by some factor and the set performed by another factor. But we have not incorporated the possibility that some subset of the tasks carried out by a given factor are especially complementary to a particular subset of those discharged by another. Such circumstances can arise when the technology requires certain groups of tasks to be performed in closed proximity. For example, the tasks performed by a nurse during surgery are most valuable when the surgeon is nearby. Similarly, technicians who are engaged in data entry are most productive when their computers are close at hand. To capture such complementarities, we need to enrich the cost functions for offshoring to allow for interdependencies between subsets of tasks.

Second, we have assumed throughout our analysis that transporting partially processed goods is costless. That is, we have included in our model the cost that arises from having a task performed remotely, but not the cost that may result from shipping the cumulative product of a subset of tasks. Our assumptions capture well the sorts of task trade conveyed electronically and increasingly fits a world in which many physical components can be transported at relatively low cost. However, in circumstances in which sets of tasks result in intermediate goods that are costly to move, a firm may need to consider grouping tasks so as to economize on shipping costs. We would like to incorporate such considerations in our future research, but suspect that this task may prove to be challenging.

We hope that the flexibility and tractability of our approach to task trade will render it useful for addressing additional questions. For example, one might reconsider the tenets of trade policy. When offshoring is possible, optimal policy should target tasks, not goods. This suggests that trade taxes should be levied on imported and exported value added, not on the full value of traded goods. Moreover, the nonphysical nature of much of this trade raises enforcement problems for the tax authorities. Hence, one might study the nature of second-best tariffs and export taxes on goods in the presence of task trade and assess the losses that result from the failure to tax value added and the inability to tax some tasks at all.

On the empirical side, we would dearly like to assess the magnitudes of the productivity, relative-price, and labor-supply effects. Research aimed at measuring these effects faces a daunting challenge, however, inasmuch as almost all current goods' trade data pertain to gross flows rather than to value added. The globalization of production processes mandates a new approach to trade data collection, one that records international transactions, much like domestic transactions have been recorded for many years. One source of hope is the data on trade in services, which in many cases is already recorded in value added terms.

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