Trading Tasks: A Simple Theory of Offshoring[*]

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Abstract

For centuries, most international trade involved an exchange of complete goods. But, with recent improvements in transportation and communications technology, it increasingly entails different countries adding value to global supply chains, or what might be called "trade in tasks." We propose a new conceptualization of the global production process that focuses on tradable 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 results from reductions in the cost of trading goods in other neoclassical frameworks.

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JEL Classification: F11, F16

1   Introduction

The nature of international trade has changed. For centuries, trade largely entailed an exchange of complete *goods*. Now it increasingly involves bits of value being added in many different locations, or what might be called trade in *tasks*. The familiar paradigm of trade theory—which conceptualizes the production process as generating finished goods from bundles of inputs combined at a single plant—was well suited for studying the trade of yesteryear. But the globalization of production and the evolving international division of labor suggest the need for a new paradigm, one that puts task trade at center stage.

Adam Smith famously described the division of labor in an English pin factory of the late eighteenth century. As he noted, the key to high productivity is specialization by task; by performing a single operation repeatedly, each worker can improve his "dexterity" and the enterprise can thereby maximize its average output. Transportation and communication were exceedingly slow and costly in Adam Smith's time. Therefore, specialization required proximity, so that the functions of different workers could be coordinated and their partially processed output could be shared. The industrial factory was a critical organizational advance that enabled firms to reap the productivity gains from the division of labor.

For most of the subsequent two centuries, the high cost of moving instructions and goods dictated agglomeration in production. But revolutionary advances in transportation and (especially) communications technology have weakened the link between 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. In this paper, we develop a simple and tractable model of offshoring that features such trade in tasks.

Hard evidence on the growing scale of task trade is difficult to come by, for several reasons. First, trade data are collected and reported as gross flows rather than as foreign value added, making it difficult to attribute tasks to the countries where they were performed. Second, some of this trade—especially the tasks involving businesses services—leaves no paper

trail.[1] Notwithstanding these measurement problems, hints of the global disintegration of the production process abound.[2] For example the OECD estimates trade flows of intermediate goods by assuming that the ratio of imported inputs to domestically produced inputs in a particular industry category matches the ratio of total imports to total domestic output in that category, Using their data, we calculate that the share of imported inputs in total inputs used by goods-producing sectors in the United States rose from 7 percent in 1972 to 18 percent in 2000. Intra-firm trade, which mostly reflects the international division of labor within multinational enterprises, accounted for 47 percent of U.S. total imports in 2005, and is growing rapidly in recent years for U.S. trade with China and several other Asian countries. As for evidence on the offshoring of tasks that do not require the shipment of physical products, many commentators have focused on trade in Business, Professional and Technical (BPT) services, a category that includes such activities as accounting and bookkeeping, information and data processing, computer programming, and management and consulting services. In the United States, imports of BPT services have increased by more than 66 percent in real terms in the seven years from 1997 to 2004.[3]

Of course, much has been written about offshoring.[4] Part of this literature focuses on firms' choices of organizational form.[5] Researchers have asked: When will a firm choose to be vertically integrated and when will it buy customized components from an arms-length supplier? If a firm engages in outsourcing, when will it choose a domestic partner and when a foreign partner? And how should a firm arrange its hierarchical production teams to facilitate intra-firm information flows? Although these are interesting questions, the models used to

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[1]See National Research Council (2006) and Government Accountability Office (2004) for an in-depth discussions of the problems that arise in measuring offshoring.

[2]Many researchers have provided evidence that bears on the increasing globalization of the production process. See, for example, Campa and Goldberg (1997), Hummels, Rapoport and Yi (1998), Yeats (2001), Hummels, Ishii and Yi (2001), and Hanson, Mataloni and Slaughter (2001, 2005).

[3]The OECD STAN database provides data for some countries on the share of imported inputs in total inputs, and on the value of trade in various services categories. Between 1990 and 2000 the share of imported inputs increased by 17 percentage points (pp) in Austria, 8 pp in Canada, 5 pp in Germany, 0.2 pp in Japan and 0.5 pp in the United States, while it decreased by 2.6 pp in the United Kingdom. Between 1993 and 2003, real imports of 'Other Business Services,' which include accounting, business management, and consulting, increased by 41% in Canada, 32% in France, 46% in Germany, 102% in the United States, and 116% in the United Kindom, while they decreased by 45% in Austria and 30% in Japan.

[4]The terms offshoring and outsourcing are sometimes used interchangeably, but we believe that such usage is confusing. We prefer to use "offshoring" to mean the performance of tasks in a country different from where a firm's headquarters are located and reserve "outsourcing" for the performance of tasks under some contractual arrangement by an unrelated party. Thus, offshoring can be conducted in-house or at arms-length, while outsourcing can be performed in a domestic or foreign location.

[5]See, for example, McLaren (2000), Grossman and Helpman (2002, 2004, 2005), Antràs (2003), Marin and Verdier (2003), Antràs and Helpman (2004), and Antràs, Garicano and Rossi-Hansberg (2006a, 2006b)

address them 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. For the most part, this research has not focused on the overall implications of the disintegration of the production process for resource allocation, welfare, and the distribution of income.

Another branch of literature models "fragmentation" as the breakdown of a production process for some good into two component parts.[6] Initially, the good can be produced according to a standard, integrated production function. Subsequently, it becomes possible to generate output by performing each of two exogenously-specified sub-processes, or fragments. These fragments, it is assumed, can be separated in space. This literature has studied how technological improvements of this sort affect trade flows, welfare, and factor prices. This research poses apt questions and generates some interesting examples and insights. But, results depend on details about which production process can be disintegrated and it is not easy to glean general principles from the cases that have been considered. Nor do the models lend themselves readily to analysis of new issues, because firms in the model make no marginal decisions about how to organize production and there are many different configurations that could characterize an equilibrium. Moreover, the modeling of fragmentation as a discrete choice makes it difficult to study the evolution of task trade over time.

Our approach begins with a different conceptualization of the production process. We assume that the production of every good requires the performance of a continuum of tasks by each of the factors of production. By highlighting the tasks needed to generate output, we allow for the possibility that tasks might be performed in different locations and that the organization of production can be varied continuously.[7] In our model, firms are motivated to offshore tasks by the prospect of factor-cost savings. But they recognize that some tasks can be performed remotely more easily than others. The set of tasks that are traded in each industry is determined endogenously so that the cost of the marginal task is equalized across locations.

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[6]See, for example, Jones and Kierzkowski (1990, 2001), Deardorff (2001a, 2001b) and Kohler (2004).

[7]Dixit and Grossman (1982) and Feenstra and Hanson (1996) use a related approach to study an economy in which final goods are assembled using a continuum of intermediate goods produced with several factors. Their conceptualization differs from ours in that what determines the set of goods produced abroad is not the different trading costs of intermediate goods but only the countries's factor endowments, since all intermediate goods are traded costelessly. Yi (2003) studies trade in intermediate goods in a model where trading these partially processed goods, not tasks, is costly.

Several authors have written about the nature of tasks that are good candidates for off-shoring. For example, Autor, Levy and Murnane (2002) distinguish between "routine" tasks that can be well described by deductive rules and "nonroutine" tasks that require pattern recognition and inductive reasoning. Levy and Murnane (2004) argue that the routine tasks are easier to move offshore than the others, because the relevant information can be exchanged with fewer misunderstandings. Similarly, Leamer and Storper (2001) draw a distinction between tasks that require *codifiable* information and those that require *tacit* information. The former, they argue, are more suitable to perform at a distance, because instructions can be expressed in symbols and headquarters can more easily monitor whether the indicated steps have been followed. Communication of tacit information, in contrast, requires that parties "know" one another and is best accomplished when they have a shared experiential background. It is often more difficult to monitor successful completion of tasks that require tacit understanding, so that relationships and frequent contact become more critical for good performance. Finally, Blinder (2006) develops an alternative dichotomy between activities that require physical contact and geographic proximity and those that generate outputs that can be delivered impersonally and from a distance. All of these authors stress the point that there is a less than perfect relationship between the suitability of a task for offshoring and the level of skill required to perform the job. For the purposes of our simple model, we do not need to subscribe to any particular explanation for why some tasks can be performed remotely more effectively than others. Rather, we just need to accept that tasks differ in this respect even if the skills required to perform them are the same. Our framework can readily capture the reality that task trade takes place at different skill levels.

Our approach can accommodate any number of sectors, any number of primary factors, and a variety of market structures. But, to keep matters simple, we develop the model in Section 2 with two industries, perfect competition, and an arbitrary number of factors greater than one. We use the model in the remainder of the paper to address an important and topical question, namely: How do improvements in the opportunities for offshoring affect the wages of different types of labor?

The information technology revolution and other innovations have facilitated task trade across a wide range of industries that produce very different types of goods and services. Indeed, some back-office functions such as bookkeeping and customer relations are common to most industries and are candidates for offshoring in all of them. No doubt the improvements in communication and transportation technology have reduced the costs of offshoring more

in some industries than in others. But, we know of no evidence that suggests a systematic relationship between the ease of offshoring a given fraction of, say, low-skill tasks and the overall skill intensity of the industry. Accordingly, we choose as our baseline assumption that the distributions of trade costs for tasks requiring a given skill level are the same in the two industries. We model the technological advancements in communication and transportation as a proportional reduction in the cost of offshoring tasks requiring a given skill level across both sectors of the economy.

In Section 3, we derive a useful decomposition of the impact of an economy-wide decrease in the cost of offshoring low-skill tasks on the wages of low-skilled workers. In general, a fall in offshoring costs for 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 has not been previously identified in the literature, is present in all trading environments and it always works to the benefit of low-skilled labor. A relative-price effect occurs when a fall in offshoring costs alters a large country's terms of trade. The relative price of a good moves in the opposite direction 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 general-equilibrium 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.

In the succeeding three subsections we examine these effects in more detail. Section 3.1 highlights the productivity effect in a small, Heckscher-Ohlin economy. In a small economy, the terms of trade are, of course, fixed, so there is no relative-price effect. And, with two factors of production and two produced goods, wages do not respond to factor supplies, so the labor-supply effect vanishes. This leaves the positive productivity effect as the only remaining force. We show that improvements in the technology for offshoring low-skill tasks are isomorphic in this case to (low-skilled) labor-augmenting technological progress and that, surprisingly, the real wage for low-skilled labor must *rise*. In Section 3.2, we introduce the relative-price effect by focusing on a large, Heckscher-Ohlin economy. Again, there is no labor-supply effect and again a reduction in the cost of offshoring low-skill tasks is like (low-skilled) labor-augmenting technological progress in the source country. This time, however, the relative price of the skill-intensive good rises, which generates a countervailing effect on

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real wages of low-skilled workers via the Stolper-Samuelson mechanism. Finally, in Section 3.3, we investigate the labor-supply effect, which is present whenever there are more factors than produced goods. The simplest such environment arises when the advanced country specializes in the production of a single good. We derive simple formulas for the productivity effect and the labor-supply effect on low-skill wages and discuss conditions under which each is likely to dominate. We show that the productivity effect is small when the range of offshored tasks is small, but it can exceed the labor-supply effect when the initial volume of task trade is large.

Arguably, public concerns about offshoring in advanced countries have been inspired by the migration abroad of white-collar tasks in computer programming, accounting, and the like. In Section 4, we introduce the possibility of offshoring tasks that require skilled labor. As such offshoring becomes more economical, a productivity effect bolsters the income of high-skilled workers in the advanced countries. As with the offshoring of low-skill tasks, this positive effect must be weighed against the relative-price and factor-supply effects, which are present in some environments. An interesting case to consider is one in which the ease of offshoring is independent of the skill level of the task. Then, in a large economy, a reduction in offshoring costs boosts the productivity of all factors similarly, so reductions in offshoring costs are equivalent to Hicks-neutral technological progress.

We summarize our results in a concluding section and discuss other potential uses of our framework. An appendix treats the technical complications that can arise when the cost of offshoring some tasks is the same as that for others.

2   Toward a New Paradigm

We conceptualize the production process in terms of tasks. Each task requires the input of some 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; for example, 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, and employing 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.

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 possibilities, then each task must be performed at a fixed intensity in order to produce a unit of output. That is, each of the unit measure 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 $f = \{L, H, \dots\}$, 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.

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[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.

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

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 4.

We index the L-tasks in an industry by $i \in [0, 1]$ and order them so that the costs of offshoring are non-decreasing. 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 $\beta t_j(i)$ times as many units of foreign labor as would be needed of domestic labor if the task was performed locally. Here, β is a shift parameter that we will use in Section 3 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 takes up the case in which the schedule has flat portions.[10]

In which industry is it easier to offshore the tasks performed by low-skilled labor? Note that this is different from asking whether it is easier to offshore tasks performed by low-skilled labor or those performed by high-skilled labor. 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, 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*). And 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 3.1.

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[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 the 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 sub-tasks that are not exactly the same, then it may be plausible to assume that all finite measures of tasks bear slightly different offshoring costs.

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 accept thereby 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.

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 to offshore some tasks. Firms offshore L-tasks in order to take advantage of the lower foreign wage, but they bear a cost for doing so that varies with the nature of the task. In each industry, the marginal task performed at home has an index I such that the wage savings just balance the offshoring costs, or

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

In a competitive industry, the price of consumer good j 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

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[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.

L-tasks, we have

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

where s denotes the high-skill wage and we have suppressed the arguments in the functions for the factor intensities for the moment. 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 low-skilled workers includes the costs of the "extra" inputs that are needed to do their jobs from a distance. The "dots" at the end of the inequality leave open the possibility that there may be 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

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

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 $\Omega(I) < 1$ 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 firms offshore some tasks.

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, since both industries face the same incentives to trade tasks, as given by (1). 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

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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. 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.

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 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 3.2 below.

3 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 to 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.

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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 (log) change in the wage of low-skilled labor as

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

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 ($\hat{\Omega} < 0$).[12] 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, exactly 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 Stolper and 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 the relative price of the labor-intensive good ($\hat{p} < 0$). So, the relative-price effect typically works to the disadvantage of low-skilled labor, as we will see in Section 3.2.

We refer to the final term in (6) as the *labor-supply effect*. As technological improvements in communications 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 economy, 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 $dI/(1 - I)$

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[12]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 $I > 0$.

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. There may be, of course, indirect effects on the average cost of H-tasks 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.

3.1 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, and it easily can dominate the other effects of task trade on domestic wages. We devote this section to studying it in some detail.

The productivity effects is 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.

Assuming that both industries are active in equilibrium, the zero-profit conditions imply[13]

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

and

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

Notice that production techniques are determined by 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. The relative-price effects are absent ($\mu_1 = \mu_3 = 0$), because terms of trade are exogenous in a small economy. And 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., $t(I) = (1 - I)^{-\eta}$). These conditions guarantee 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

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

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 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 $1/\left(\beta\tau(i)\right)$ 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.* So, 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 a world of perfect competition—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 only possible to offshore tasks 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.[14] 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), when 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. And they 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, while 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.

More generally, if the cost schedules for offshoring differ across the industries in arbitrary ways, then the wage of a low-skilled worker rises in response to an improvement in offshoring technologies if and only if

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

where Ω_x is defined analogously to Ω_y. That is, low-skill wages rise as long as the productivity gain in the skill-intensive sector is not too much larger than that in the labor-intensive sector.

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[14] 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.

Meanwhile, the wage of a high-skilled worker rises if and only if

$$-\hat{\Omega}_x > -\hat{\Omega}_y \ .$$

As an example, consider the case in which $t_x(i) = \alpha t_y(i)$. Then, for a given I, $-\hat{\Omega}_x(I) = -\hat{\Omega}_y(I)$ for all α. Cost minimization in the two sectors implies $w = \beta t_x(I_x)w^* = \beta t_y(I_y)w^*$ and since both cost functions are strictly increasing, $I_x > I_y$ if and only if $\alpha < 1$; i.e., if and only if task trade is costlier in the labor-intensive sector than in the skill-intensive sector. If, as discussed before in the context of the size of the productivity effect, either $\eta_x(I_x) < 1$ and $\eta_y(I_y) < 1$ or η_x and η_y are constants, then $-\hat{\Omega}_x > -\hat{\Omega}_y$ for $\alpha < 1$ and so high-skill wages rise with decreases in offshoring costs. But even in the case where $\alpha < 1$, the productivity effect will boost the wages of low-skilled workers as long as the industry difference in offshoring costs is not too great, because $\theta_{Hx}/\theta_{Lx} > \theta_{Hy}/\theta_{Ly}$.

3.2 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-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

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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 cost-minimizing techniques are the same in the two countries; i.e., $a_{fj} = a_{fj}^*$. 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[15]

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

and

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

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

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[15] 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.

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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 $(dI > 0)$.[16] 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. 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, while domestic low-skilled labor may gain or lose, depending on the relative sizes of the productivity and relative-price effects. 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.

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. As should be clear, the analogy between reductions in the cost of offshoring and labor-augmenting

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[16]Note that

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

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.

3.3 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 thus far considered, 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. However, we can elucidate this effect more clearly in an even simpler environment. To this end, we consider a small economy as in Section 3.1 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 decrease in the cost of trading tasks ($d\beta < 0$). Differentiating (8) gives

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

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

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

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 12. 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

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initially is performed 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 $I = 0$.[17]

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

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

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

4   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. For example, workers in India are reported to be reading x-rays (Pollak, 2003), developing software (Thurm, 2004), preparing tax forms (Robertson et al., 2005), and even performing heart surgery on American patients (Baker et al., 2006). 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

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[17]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 $I = 0$.

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 that

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

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

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

If the home country is incompletely specialized, the zero-profit conditions imply

$$1 = \Omega_L w_L a_{Lx} \left(\Omega_L w_L / \Omega_H w_H\right) + \Omega_H w_H a_{Hx} \left(\Omega_L w_L / \Omega_H w_H\right) \tag{19}$$

and

$$p = \Omega_L w_L a_{Ly} \left(\Omega_L w_L / \Omega_H w_H\right) + \Omega_H w_H a_{Hy} \left(\Omega_L w_L / \Omega_H w_H\right) , \tag{20}$$

where

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

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 $\Omega_L w_L$ and $\Omega_H w_H$ 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 tasks leaves $\Omega_L w_L$ and $\Omega_H w_H$ 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

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high-skilled jobs spurs additional offshoring of H-tasks, with attendant decreases in average costs of H-tasks and an increase in high-skilled 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 consequences.

An interesting special case arises when the distribution of trading costs for H-tasks is the same as that 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 3.2, 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.[18]

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.

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[18]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 $I_L = I_H$.

5   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 has been no simple paradigm with which 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 paradigm 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 acts like a boost in 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, other neoclassical 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 traded 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 that is 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 results 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 non-physical nature of much of this trade raises enforcement problems for the tax authorities. So, 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. However, research aimed at measuring these effects faces a daunting challenge inasmuch as almost all current 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.

6 Appendix

In this appendix, we extend the analysis to include the possibility that the offshoring cost schedule, $t(i)$, has flat portions along which $t'(i) = 0$. Recall that we normalized the measure of tasks to one and assumed that all tasks using a given factor require the same input of that factor when performed at home. This normalization is without loss of generality, provided that we can divide any bigger task into subtasks and assign multiple indexes to them. However, in doing so, the possibility arises that several of these subtasks will bear the same offshoring costs. So, we need to allow for flats in the $t(i)$ schedule to accommodate tasks of different sizes. We proceed to reconsider the small Heckscher-Ohlin economy, the large Heckscher-Ohlin economy and the small, specialized economy, following the progression of Section 3.

To make our points, it suffices to consider a $t(i)$ schedule with one flat portion for $i \in [i_1, i_2]$; i.e., $t'(i) > 0$ for $i < i_1$, $t'(i) = 0$ for $i_1 < i < i_2$ and $t'(i) > 0$ for $i > i_2$. We continue to assume that $t(i)$ is continuously differentiable everywhere except at i_1 and i_2.

6.1 Small Heckscher-Ohlin Economy

For the small Heckscher-Ohlin economy, we will substantiate the following claims: (1) the low-skill wage is a continuous and everywhere decreasing function of β, possibly with a kink; (2) there is a unique value of β that we denote by β_{12} for which the equilibrium I may fall on the flat portion of the $t(i)$ schedule; (3) for $\beta = \beta_{12}$, there are multiple equilibria with I ranging from i_1 to i_2; and (4) the correspondence between I and β is discontinuous at $\beta = \beta_{12}$, but continuous elsewhere. In other words, the equilibrium "almost never" falls on the flat portion of $t(i)$ and, even if it does, our conclusions about the beneficial wage effects of an improvement in the offshoring technology apply for all parameter values.

Before proving these claims, we seek to clarify them further in two figures. Figure 1 shows the wage of low-skilled workers as a function of β. For high values of β such that $\beta > \beta_{12}$, there is little offshoring ($I < i_1$). In such circumstances a decline in β leads to an expansion of the range of tasks performed offshore, as shown in Figure 2, and an increase in the low-skill wage. The wage increase matches the productivity effect, which can be calculated using the formula in the main text. As β falls further, it reaches the unique value β_{12} at which the equilibrium I can fall anywhere along the vertical section of the curve shown in Figure 2. All of these equilibria share the same factor prices but differ in resource allocation. However,

as β falls from just above β_{12} to just below this value, the wage response is continuous, as depicted in Figure 1. For further reductions in β, the analysis mirrors that in the main text. Notice that Figure 1 displays a kink in the wage function at $\beta = \beta_{12}$. Such a kink exists if and only if $t'(i_1 - \varepsilon)$ differs from $t'(i_2 + \varepsilon)$ as $\varepsilon \to 0$. However, it is inconsequential to our analysis.
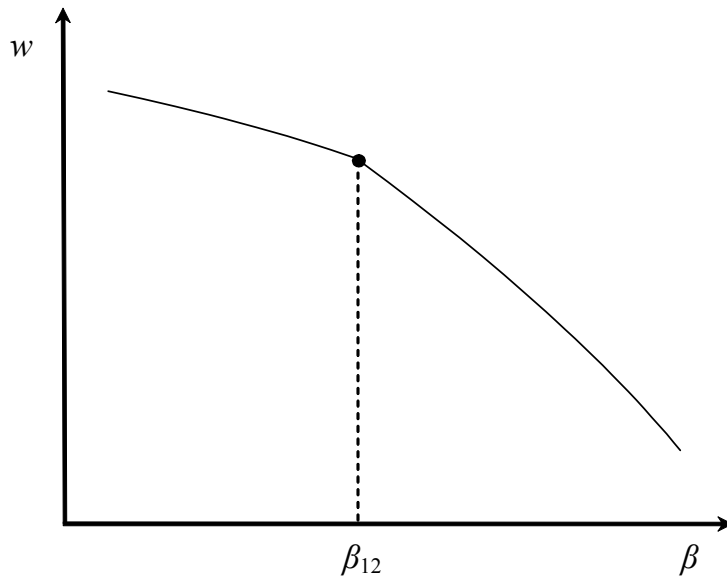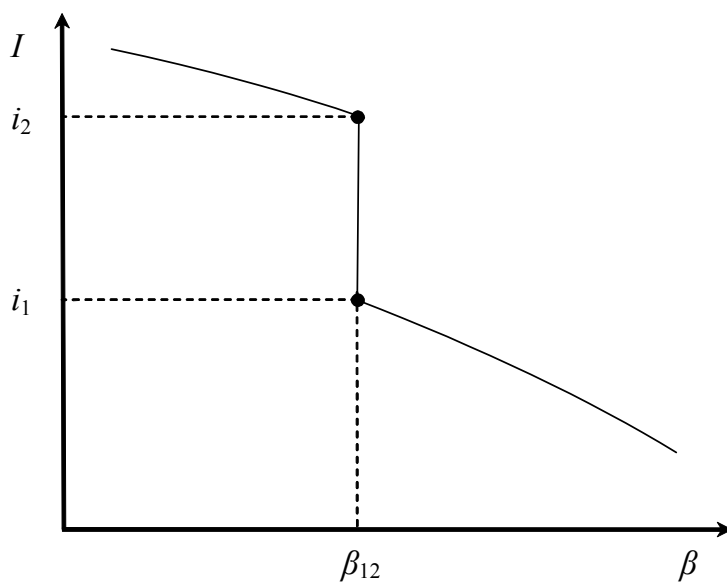

Figure 1

Figure 2

To prove that I and w must respond to a decline in β as depicted in the figures, suppose to the contrary that the equilibrium I varies smoothly with β in the range where $I \in (i_1, i_2)$; i.e., $dI/d\beta$ is finite for $I \in (i_1, i_2)$. For I in this range, $t'(I)dI/d\beta = 0$, so $\Omega'(I)dI/d\beta = 0$. Then (8) and (9) imply that $\hat{w}/\hat{\beta} = 0$. But (1) implies that $\hat{w} = \hat{\beta} + (t'(I)/t(I))\,dI = \hat{\beta}$, or $\hat{w}/\hat{\beta} = 1$. This is a contradiction, so $dI/d\beta = \infty$ for all $I \in (i_1, i_2)$, as shown in Figure 2.

At $\beta = \beta_{12}$, $I \in [i_1, i_2]$ and $t(I) = t(i_1) = t(i_2)$. Therefore,[19] $\Omega(I) = \Omega(i_1) = \Omega(i_2)$ and so (8) and (9) are satisfied for a common (w, s) for all $I \in [i_1, i_2]$. In this range, there are multiple equilibria with the same factor prices but different values of x and y to satisfy (4) and (5). Then, as β falls from β_{12} to something a bit smaller, I increases from an arbitrary point in $[i_1, i_2]$ to a point just outside that region, which means that $t(I)$ rises, as does $-\Omega(I)$. Thus, the wage must rise (smoothly) for (8) and (9) to be satisfied. Moreover, let us define $d\Omega(I) = \Omega(I + dI) - \Omega(I)$ for $I \in [i_1, i_2]$, where (with slight abuse of notation) dI includes both the jump to the edge of the flat region and the small change in I that results when β falls slightly below β_{12}. Then $\hat{w} = -\hat{\Omega}(I)$ for all values of I, just as before.

6.2 Large Heckscher-Ohlin Economy

In a large economy, the relative price adjusts to a fall in β. Nonetheless, we can show that w is a continuous and everywhere decreasing function of β in this environment as well. Moreover, there is a unique value of β for which the equilibrium I may fall on the flat portion of the $t(i)$ schedule and the correspondence between I and β is discontinuous at this point.

The argument is similar to that in the previous section. Suppose again that $dI/d\beta$ is finite for $I \in (i_1, i_2)$, so that $t'(I)dI/d\beta = \Omega'(I)dI/d\beta = 0$. By (12) and (13), the fact that Ω is constant implies that $(x + x^*)/(y + y^*)$ is constant, which in turn implies that p is constant. With p constant, Ω constant, and no labor-supply effect, (6) implies that $\hat{w} = 0$. But (10), (11) and $\hat{p} = 0$ imply that $\hat{w}^* = 0$. Again, we must have $\hat{w} = \hat{w}^* + \hat{\beta} + (t'(I)/t(I))\,dI$ by the optimality condition for offshoring, which with $\hat{w}^* = t'(I) = 0$ implies $\hat{w} = \hat{\beta}$. So we have the same sort of contradiction as before. We conclude that our analysis in Section 3.2 of the large Heckscher-Ohlin economy carries over to the case in which $t'(i)$ has flat portions.

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[19] Note that, for $I \in (i_1, i_2)$,

$$\Omega(I) = 1 - I + \frac{\int_0^I t(i)di}{t(I)} = 1 - I + \frac{\int_0^{i_1} t(i)di + (I - i_1)\,t(i_1)}{t(i_1)} = 1 - i_1 + \frac{\int_0^{i_1} t(i)di}{t(i_1)}\,,$$

which is independent of I.

6.3 Small, Specialized Economy

Finally we consider a small country that produces a single good, so that the labor-supply effect operates. In this case, contrary to the previous two, it is possible for I to vary smoothly with changes in β when $I \in (i_1, i_2)$. When I is on the flat portion of the $t(i)$ schedule, a change in β generates a labor-supply effect that causes the low-skill wage to fall by the full extent of the shift in the offshoring cost schedule; i.e., $\hat{w} = \hat{\beta}$. Then, $dI/d\beta > 0$ is finite, but since $t'(i) = 0$ for $I \in (i_1, i_2)$, $w = \beta t(I) w^*$ continues to be satisfied. The change in I can be computed from $\hat{w} = \hat{\beta}$ and (16), which imply that

$$\frac{dI}{d\beta} = -\frac{\sigma_x}{1 - \theta_{Lx}} \frac{1 - I}{\beta} \ .$$

Now, as long as I remains on the flat portion of $t(i)$, the productivity effect of an improvement in the offshoring technology is nil and low-skill wage falls.

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7 References

Antràs, Pol, (2003), "Firms, Contracts, and Trade Structure," *Quarterly Journal of Economics*, 118:4, 1375-1418.

Antràs, Pol and Elhanan Helpman, (2004), "Global Sourcing," *Journal of Political Economy*, 112:3, 552-580.

Antràs, Pol, Luis Garicano and Esteban Rossi-Hansberg, (2006a), "Offshoring in a Knowledge Economy," *Quarterly Journal of Economics*, 121:1, 31-77.

Antràs, Pol, Luis Garicano and Esteban Rossi-Hansberg, (2006b), "Organizing Offshoring: Middle Managers and Communication Costs," NBER Working Paper 12196.

Autor David, Frank Levy and Richard Murnane, (2003), "The Skill Content Of Recent Technological Change: An Empirical Exploration," *Quarterly Journal of Economics*, 118:4, 1279-1333.

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

Blinder, Alan S., (2006), "Offshoring: The Next Industrial Revolution?" *Foreign Affairs*, 85:2, 113-128.

Campa, José M., and Linda S. Goldberg, (1997), "The Evolving External Orientation of Manufacturing Industries: Evidence from four Countries," *Federal Reserve Bank of New York Economic Policy Review*, 3:2, 53-81.

Deardorff, Alan V., (2001a), "Fragmentation across Cones," in S.W. Arndt and H. Kierzkowski, eds., *Fragmentation: New Production Patterns in the World Economy*, Oxford: Oxford University Press.

Deardorff, Alan V., (2001b), "Fragmentation in Simple Trade Models," *North American Journal of Economics and Finance*, 12: 2, 121-137.

Dixit, Avinash and Gene M. Grossman, (1982), "Trade and Protection with Multi-Stage Production," *Review of Economic Studies*, 49:4, 583-594.

Feenstra Robert C. and Gordon H. Hanson, (1996), "Foreign Investment, Outsourcing and Relative Wages," in R.C. Feenstra, G.M. Grossman and D.A. Irwin, eds., *The Political Economy of Trade Policy: Papers in Honor of Jagdish Bhagwati*, Cambridge, MA: MIT Press.

Government Accountability Office, (2004), *International Trade: Current Government Data Provide Limited Insight into Offshoring of Services*, GAO-04-932.

Grossman, Gene M. and Elhanan Helpman, (2002), "Integration versus Outsourcing in Industry Equilibrium," *Quarterly Journal of Economics*, 117: 1, 85-120.

Grossman, Gene M. and Elhanan Helpman, (2004), "Managerial Incentives and the International Organization of Production," *Journal of International Economics*, 63, 237-262.

Grossman, Gene M. and Elhanan Helpman, (2005), "Outsourcing in a Global Economy," *Review of Economic Studies*, 72:1, 135-159.

Hanson, Gordon H., Raymond J. Mataloni and Matthew J. Slaughter, (2001), "Expansion Strategies of U.S. Multinational Firms," in D. Rodrik and S.M. Collins, eds., *Brookings Trade Forum 2001*.

Hanson, Gordon H., Raymond J. Mataloni and Matthew J. Slaughter, (2005), "Vertical Production Networks in Multinational Firms," *Review of Economics and Statistics*, 87:4, 664-678.

Hummels, David, Jun Ishii and Kei-Mu Yi, (2001), "The Nature and Growth of Vertical Specialization in World Trade," *Journal of International Economics*, 54:1, 75-96.

Hummels, David, Dana Rapoport, and Kei-Mu Yi, (1998), "Vertical Specialization and the Changing Nature of World Trade," *Federal Reserve Bank of New York Economic Policy Review*, 4:2, 79-99.

Jones, Ronald W. and Henryk Kierzkowski, (2001), "Globalization and the Consequences of International Fragmentation," in R. Dornbusch, ed., *Money, Capital Mobility and Trade: Essays in Honor of Robert A. Mundell*, Cambridge, MA: The MIT Press.

Kohler, Wilhelm (2004), "Aspects of International Fragmentation," *Review of International Economics*, 12:5, 793-816.

Leamer, Edward E., (1998), "In Search of Stolper-Samuelson Linkages between International Trade and Lower Wages," in S.M. Collins, ed., *Imports, Exports, and the American Worker*, Washington, D.C.: The Brookings Institution Press, 141-203.

Leamer, Edward E. and Michael Storper, (2001), "The Economic Geography of the Internet Age," *Journal of International Business Studies*, 32:4, 641-665.

Levy, Frank and Richard Murnane, (2004), *The New Division of Labor*, Princeton: Princeton University Press.

Marin, Dalia and Thierry A. Verdier, (2003), "Globalization and the Empowerment of Talent," CEPR Discussion Paper No. 4129.

McLaren, John E., (2000), " 'Globalization' and Vertical Integration," *American Economic Review*, 90:5, 1239-1254.

National Research Council, (2006), *Analyzing the U.S. Content of Imports and the Foreign Content of Exports,*Washington, DC: The National Academies Press.

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

Robertson Jesse, Dan Stone, Liza Niedewanger, Matthew Grocki, Erica Martin and Ed Smith, (2005), "Offshore Outsourcing of Tax-Return Preparation," *CPA Journal,* June.

Stolper, Wolfgang F. and Paul A. Samuelson, (1941), "Protection and Real Wages," *Review of Economic Studies*, 9:1, 58-73.

Trefler, Daniel, (1995), "The Case of Missing Trade and Other Mysteries," *American Economic Review*, 85:5, 1029-1046.

Thurm, Scott, (2004), "Tough Shift – Lesson in India: Not Every Job Translates Overseas," *New York Times*, March 3.

Yeats, Alexander J., (2001), "Just How Big Is Global Production Sharing?" in S.W. Arndt and H. Kierzkowski, eds., *Fragmentation: New Production Patterns in the World Economy*, Oxford: Oxford University Press.

Yi, Kei-Mu, (2003), "Can Vertical Specialization Explain the Growth of World Trade?," *Journal of Political Economy*, 111:1, 52-102.