CENTER FOR LATIN AMERICAN MONETARY STUDIES

An Offshoring Setup

Martín Tobal

July 2013

Research Papers

11

Research Papers

11

AN OFFSHORING SETUP

Author:
Martín Tobal

Durango 54, Colonia Roma Norte, Delegación Cuauhtémoc, 06700 México D.F., México.
E-mail:publicaciones@cemla.org
http://www.cemla.org
I am deeply thankful to James Rauch for his appreciable advice and for his inestimable support. I am also particularly grateful to Gordon Hanson for his invaluable guidance. I thank Thomas Baranga, Marc Muendler and other attendees of UCSD seminars for their valuable comments and Fundación ICO, Gobierno de España for funding.

An Offshoring Setup

Martín Tobal, *Centro de Estudios Monetarios Latinoamericanos (CEMLA)*

mtobal@cemla.org

ABSTRACT

This paper builds a model of trade in final goods that differ in skill-intensity and intermediate tasks that differ in tradability. A skill -abundant country whose final goods productivity is high relative to the rest of the world is shown to import (more unskilled tasks than skilled tasks, given identical tradability schedules for the latter and the former tasks. Transition from the non-offshoring to the offshoring equilibrium yields wage and employment effects in the long run that switch from negative to positive as tradability declines, and the switches occurr at a higher tradability level for skilled tasks. The findings are consistent with the young empirical literature.

JEL Codes: *F16*

Keywords: *Offshoring; ICT Revolution and Labor Tasks.*

1 INTRODUCTION

The Information and Communication Technologies (ICT) revolution has allowed for the output of previously non-tradable labor tasks to be delivered electronically from overseas. The possibility of delivering output electronically has reduced the offshoring costs of the labor tasks, leading to the abrupt increase in service offshoring documented by Amiti and Wei (2005, 2009), Crinò (2009,2010), and Trefler (2006). The boom of service offshoring has received increasing attention in the media and academic research in recent years.[1]

I develop a model of service offshoring in order to investigate the wage and employment impacts for a country with high final goods productivity and abundant skilled (educated) labor relative to the rest of the world. I consider two sectors that have different skill-intensities and conceptualize production in terms of tasks that vary in tradability. The costs of offshoring tasks are represented by a tradability index that varies smoothly across the tasks in the manner of Grossman and Rossi-Hansberg (2008) (henceforth GRH).

In this setup a task's propensity to be offshored depends on two labor dimensions: tradability and skill-intensity. I consider skilled tasks and unskilled tasks and identify a cutoff traded task for each type of task, below which tasks are offshored due to high tradability and above which tasks are produced domestically due to low tradability. The cutoff traded task is greater for the unskilled tasks since the skill premium differs across regions: the skill premium is lower in the skilled-abundant country and therefore this country reaps larger savings by offshoring the unskilled tasks.

The two labor dimensions are also relevant to understanding the wage impacts of service offshoring. Wages are fully determined by demands since my putty-clay technology locks labor into tasks making supplies inelastic in the short run. By reducing offshoring costs, the ICT revolution provides firms with the possibility of undertaking previously non-tradable tasks abroad at lower prices. This possibility reduces the demands for domestically produced tasks and therefore exerts a wage-reducing effect. The wage-reducing effect increases smoothly with tradability, reflecting that service offshoring more strongly increases the exposure to foreign

[1] Mankiw and Swagel (2006) survey the comments that the topic has received in the media.

competition of the most tradable tasks. Along these lines, the wage-reducing effect is sufficiently weak for the least tradable tasks that their wage increases. The impact on the wage of a task also depends on its skill-intensity as noted below.

Perceiving a higher wage in the least tradable tasks, workers transit from the most tradable tasks to the least tradable tasks. Before transitioning, workers must acquire the knowledge that is specific to their new task through a retraining process. Retraining and task-transitioning lead to a reallocation of employment: employment decreases in the most tradable tasks that workers leave and increases in the least tradable tasks to which workers transition. The costs of retraining vary within tasks since workers fulfilling the same task are distributed based on their ability to retrain according to a distribution that is identical across tasks (this assumption requires that workers do not expect the ICT revolution). Under these assumptions the extent of the employment decrease in a task is based on the wage impact of offshoring: workers fulfilling tasks whose wage decreases by the greatest amount (the most tradable tasks) benefit from a higher wage increase by retraining and transitioning to the least tradable tasks. Thus, retraining is more frequent in the most tradable tasks where the decrease in employment is greater. The decrease in employment increases smoothly with tradability since the negative impact of offshoring on wages is monotonic with the tradability index.

The predictions of the model are novel to the theoretical literature since the impact of service offshoring on a worker's wage depends on the skill-intensity and degree of tradability of her task. Based on tradability and skill-intensity, the model determines a set of workers whose wage decreases (I refer to these workers sometimes as losers) and a set of workers whose wage increases (I refer to these workers sometimes as winners). Skill-intensity is not sufficient to determine these sets since workers fulfilling the least tradable tasks gain from offshoring independent of skill-intensity. On the other hand skill-intensity is necessary for determining these sets because a low skill premium makes the exposure to foreign competition stronger for the unskilled tasks and the reduction in demand for these tasks is correspondingly greater. Specifically, the set of workers who lose from service offshoring is greater for the unskilled tasks than it is for the skilled tasks. By the same token, the wage loss of an unskilled loser is greater than the wage loss of a skilled loser given tradability.

The findings of my model differ from GRH's outcomes in some important ways. In generating a greater cutoff task for unskilled labor, GRH rely on a potential negative correlation between the tradability and the skill-intensities of the tasks. In contrast, I rely on cross-country differences in factor proportions (a standard factor proportion argument): the cutoff traded task is greater for the unskilled tasks because the skill premium is lower in the skill-abundant country. Employing some features of their work and putty-clay technology, I prove the existence of a more general wage-reducing effect which does not depend on the number of factors or the number of goods. Because it is isomorphic to a labor-supply increase, GRH's wage-reducing effect reduces the wage of all tasks having the same skill-intensity by the same amount. Thus, workers are classified into winners and losers only based on the skill-intensities of workers' tasks. In contrast, the extent of my wage-reducing effect increases with tradability so that winners and losers are determined based on skill levels and tradability in my model.[2] Workers fulfilling tasks with sufficiently high offshoring costs gain from offshoring independent of their skill levels so that the typical distributional conflict arising from reductions in the costs of trading goods (based on skill levels) does not take place. Whereas in GRH the distributional conflict does not take place if the wage-increasing (productivity) effect is greater than the wage-reducing effect, this result holds unambiguously in my model. Furthermore, because the extent of my wage-reducing effect varies smoothly with tradability, some workers gain from offshoring even though their task types (tasks with the same skill-intensity and degree of tradability) are offshored. Finally, service offshoring generates employment reallocation so that employment goes to zero for all offshored tasks in GRH's setup. In my model, the employment responses to offshoring are different and vary smoothly with the tradability index within the set of offshored tasks. The smoothness of the employment responses represents an advantage when confronting the predictions of my model with data.

My model also contributes to the literature through comparative statics that yield cross-sectional predictions for countries with different characteristics. I compare offshoring effects across countries with different degrees of technological advantage (productivity) and different levels of trade isolation (different transport costs on final goods). The comparative statics show that isolation magnifies the asymmetry of the offshoring effects across skill groups: in more isolated countries, the set of skilled losers is smaller and the set of unskilled losers is greater. In contrast, the sets of unskilled losers and skilled losers are greater in more technologically advanced countries, being the key to this result that technological advantage is not diminished by importing tasks.

[2] Intuitively speaking, the ICT revolution should reduce the wage of a radiologist by more than it should reduce the wage of a physician because the job of a radiologist is more tradable. Even so, radiologists and physicians spend a similar amount of time in school.

The wage results of my model find some empirical support in the emerging empirical literature. Hummels et al. (2011) study the impact of offshoring on Danish wages over the 1995-2006 period. Employing matched worker-firm data they show that offshoring increases the high-skilled wage and decreases the low-skilled wage. Offshoring also decreases the wage of workers whose occupations involve routine tasks (more tradable tasks) by a greater amount. Crinò (2010) finds that changes in occupational wages are positively correlated with changes in occupational employment, even after controlling for variations in the occupational supply (given Crinò's results described below, this correlation indicates that wages have increased in skilled occupations whose tradability degree is low).

The smoothness of the employment changes across tasks makes my predictions consistent with the evidence on employment and switching rates across occupations. Crinò (2010) estimates the elasticity of demand to service offshoring across different USA white-collar occupations. The positive elasticities are concentrated among the skilled occupations and the negative elasticities are concentrated among the unskilled occupations.[3] A joint analysis of skill-intensity and tradability shows that service offshoring is more likely to increase employment in occupations with high skill-intensity given tradability. Offshoring also increases employment in occupations with high tradability given skill-intensity.[4] The results of the paper are also consistent with those of Trefler and Liu (2011), who map occupations with service categories to study the impact of service offshoring on switching rates across occupations. Service offshoring increases switching rates, with the increase being stronger on unskilled workers and workers fulfilling routine tasks. These increases occur after a period of time as they do in my model, where workers transition gradually to their new tasks.

I obtain the wage impacts of service offshoring by comparing an offshoring regime to a non-offshoring regime, in which the offshoring costs of the labor tasks are lower. I present the former regime in Section 2 and the later regime in Section 3, in which I also show the wage results. Employing these results, the simple retraining model that I present in Section 4 yields the

[3] In order to measure tradability, Crinò considers three job characteristics. A job is more tradable when it is routine, when it produces impersonal services, and when it is ICT-enabled. Based on these three characteristics he constructs a tradability index employing principal component analysis.

[4] Crinò employs data at the occupational level, and thus these statements require a mapping between tasks–our unit of measure– and occupations. Any reasonable mapping would make the statements true as the skill-intensity of an occupation should increase with the relative weight of its skilled tasks; and the tradability of this occupation should also increase with the tradability of its tasks.

employment impacts of service offshoring. I summarize the predictions and confront them to the findings of the emerging empirical literature in section 5. Section 6 concludes.

2 NON-OFFSHORING REGIME: TRADE IN FINAL GOODS

This section develops a task-based model of trade in final goods. The offshoring costs of the tasks are assumed to be sufficiently large that no offshoring occurs. Firms demand domestically produced tasks and workers choose a task to supply.

2.1 MODEL SETUP

I consider a world with two regions, *Home* and the *Rest of the World* (RW hereafter) and identify the variables concerning RW with a superscript asterisk (*). There are two types of goods, a skilled-intensive good denoted by Y_s and an unskilled-intensive good denoted by Y_u. Home is a small skill-abundant country with a Hicks neutral technological advantage. This country is assumed to import the unskilled-intensive good, so that the case is empirically appealing.

The two types of tasks employed for production are specific factors: the skilled tasks are only used to produce Y_s, and the unskilled tasks are only used to produce Y_u. Tasks performed using a given labor-type are assumed to require a unit of that labor. Skilled workers are distributed over a continuum whose measure equals L_s (for unskilled workers, the measure equals L_u). The measures of skilled tasks and unskilled tasks are normalized to one in the manner of GRH. The production functions are the following Cobb-Douglas employed by Acemoglu et al. (2007)

(1) $$Y_j = A\exp\left\{\int_0^1 \ln\left(z_{ij}\right)di\right\},\ i\in[0,1],\quad j=s,u,$$

(2) $$Y_j^* = \exp\left\{\int_0^1 \ln\left(z_{ij}^*\right)di\right\},\ i\in[0,1],\quad j=s,u,$$

where z_{ij} denotes usage of task i in industry j, and $A>1$ is Home's Hicks neutral technological parameter. The technology differs from GRH's in that tasks that use the same labor-type are substitutes, so that I will be able to define a specific output-constrained demand for each task as a function of its price (wage).

The goods market is perfectly competitive, and trade costs, which are of the Samuelson-Bergson iceberg type (1952), apply to both final goods. Specifically, for one unit of a product to arrive in the other region $\tau > 1$ units must be shipped.

2.2 EQUILIBRIUM IN THE NON-OFFSHORING REGIME

The set of equilibrium wages $w_{ij}\, i \in [0,1],\, j = s,u$, fulfills two requirements: the task markets clearing and the zero-profit conditions. Since Home is a small country, final goods prices are exogenous and wages must be written in terms of these exogenous variables in equilibrium.[5] I will begin by showing that clearing in the task markets implies that every task is produced. Cost minimization yields the following output-constrained demands for tasks

(3) $$z_{ij}^{d} = \left(Y_j \exp\left\{ \int_0^1 \ln\left(z_{ij}\right) di \right\} \right) / A w_{ij},\ i \in [0,1],\ j = s,u,$$

(4) $$z_{ij}^{*d} = \left(Y_j^{*} \exp\left\{ \int_0^1 \ln\left(w_{ij}^{*}\right) di \right\} \right) / w_{ij}^{*},\ i \in [0,1],\ j = s,u,$$

where z_{ij}^{d} is the output-constrained demand for task i in sector j and w_{ij} is the price of the task.

In order for a task not to be produced, its demand and supply must be zero in equilibrium. Note in equations 3 and 4 that the demand for a task goes to zero only when its price goes to infinity. The supply of a task equals zero only when another task has a strictly higher price (because a worker is able to perform any of the tasks at her skill level). However, no task can have a strictly higher price than a task whose price goes to infinity. Hence, every task is produced and therefore the price of every task having the same skill-intensity is the same in equilibrium.[6] More formally, any task markets clearing set of wages fulfills the following conditions

(5) $$w_{is} = w_s,\ \forall\, i \in [0,1],\ \ w_{iu} = w_u,\ \forall\, i \in [0,1],$$

(6) $$w_{is}^{*} = w_s^{*},\ \forall\, i \in [0,1],\ \ \ w_{is}^{*} = w_s^{*}, \forall\, i \in [0,1].$$

[5] The appendix section shows that if Home is a large country, domestic wages are written in terms of factor endowments, technologies, and transportation costs that I introduce below

[6] All tasks must have the same price so that the supply of no task equals zero.

Plugging these conditions in the demands displayed in equation 3 and 4 shows that labor of type j must be evenly allocated across the j-intensive tasks.[7, 8] Because the tasks are specific factors, the two types of goods are produced in each country and therefore there is incomplete specialization in equilibrium.

Equations 5 and 6 define market clearing in the task markets and yield, along with the zero-profit conditions, domestic wages in equilibrium. In a competitive economy where incomplete specialization holds, the zero-profit conditions are fulfilled when the effective price of any good equals its unit cost of production. Unit production costs equal marginal costs under the constant returns to scale technologies displayed above and are written as follows

$$MC_j = \exp\left\{\int_0^1 \ln\left(w_{ij}\right) di\right\} / \mathrm{A}, \quad i \in [0,1], \quad j = s, u, \tag{7}$$

$$MC_j^* = \exp\left\{\int_0^1 \ln(w_{ij}^*) di\right\}, \; i \in [0,1], \; j = s, u, \tag{8}$$

where MC_j denotes the marginal cost of producing good Y_j. I impose the task market clearing conditions in equations 8 and 9, and obtain simplified expressions for marginal costs. Equating these simplified expressions to effective prices yields the following zero-profit conditions

$$p^T = w_s / A, \quad \tau = w_u / A, \tag{9}$$

$$\tau p^T = w_s^*, \quad 1 = w_u^*, \tag{10}$$

where p^T denotes the relative price of the skilled-intensive good and τ is the measure of iceberg costs. Domestic consumers pay iceberg costs and a higher effective price for the unskilled-intensive good because Home, which is the skill-abundant country, imports this product. This implies that the unskilled to skilled wage is greater in Home than it is in RW, whenever the zero-profit conditions hold. I state this as follows

$$w_s / w_u = w_s^* / (w_u^* \tau^2) < w_s^* / w_u^*. \tag{11}$$

7 Given that all tasks have the same price in equilibrium, they are all produced in the same amount because their demands are symmetric. The demands are symmetric because they enter symmetrically in equations 1 and 2.

8 If the world were perpetually well described by the offshoring regime, even labor allocation across tasks would be Pareto efficient as this would maximize output. However, as offshoring takes place, a different labor allocation reduces retraining costs and might be Pareto-dominant.

There is evidence suggesting that unskilled to skilled wages are higher in countries with high final goods productivity and abundant skilled labor relative to RW. Psacharopoulos (1994) provides the most comprehensive survey for the pre-ICT revolution period and concludes that private schooling returns are smaller in developed nations. Acemoglu (2003) shows that unskilled to skilled wages and skill abundance are negatively correlated in Psacharopulos' sample.

In the offshoring regime the wage-reducing effect will be stronger for the unskilled workers, whenever equation 11 holds, or equivalently, Home is the skill-abundant country. In proving this statement, I will employ the wage results from this section in the form of Home-to-RW wages by skill levels. These wages are obtained by rearranging equations 9 and 10 and written as follows

$$w_s / w_s^* = A / \tau, \tag{12}$$

$$w_u / w_u^* = A\tau. \tag{13}$$

The Home-to-RW wages increase with Home's technological advantage (the Hicks neutral technological parameter). If this advantage is sufficiently great, the wages shown in equations 12 and 13 are sufficiently large that firms will offshore skilled tasks and unskilled tasks in the next section. Note also that the Home-to-RW wage differs across skill levels.

3 OFFSHORING REGIME: TRADE IN FINAL GOODS AND INTERMEDIATE TASKS

In this section I present the offshoring regime and show that the transition from the non-offshoring to the offshoring equilibrium yields real wage effects that vary across tasks having the same skill-intensity. After setting up the model and finding its equilibrium, the section runs comparative statics that yield cross-sectional predictions for countries with different characteristics.

3.1 Setup of the Service Offshoring Model

The offshoring costs of the tasks are expressed in terms of foreign labor and increase (weakly) with the i index for a given skill-intensity: a firm that performs task i abroad requires $\beta t(i)$ units of foreign labor, β being the GRH shift parameter. I will identify an endogenous cutoff traded task I, below which task are offshored due to high tradability and above which tasks are produced domestically due to low tradability. A discrete decrease in the value of β captures the abrupt reduction in offshoring costs caused by the ICT revolution.

The function describing the offshoring cost schedule $t(i)$ is assumed to be monotonic, twice differentiable and *sufficiently increasing* that only some tasks are offshored in equilibrium. Home's technological advantage is assumed to be at least as large as stated in the following assumption

$$A > \tau\beta t(0). \tag{14}$$

The bound on the technological parameter ensures that Home's skilled wage in the non-offshoring regime is sufficiently large that undertaking some of the skilled tasks abroad is less costly than undertaking these tasks in Home. Thus, whenever equation 14 holds, domestic firms will offshore at least the most tradable of the skilled tasks.

Finally, I assume putty-clay technology implying that human capital is task-specific and labor cannot be reallocated across tasks in the short-run. Thus, all domestic labor employed in offshored tasks in the non-offshoring regime continues to be employed in the same tasks in the offshoring regime, and some of the supply of these tasks is being imported. Kambourov and Manovskii (2009) provide empirical support for the putty-clay assumption and the specificity of human capital at the occupational-level: they find that occupational tenure has a wage premium after controlling for workers' experience, industry and employer tenure.[9] Buillding on Kambourov and Manovskii (2009), Ritter (2008) shows that human capital is more specific for tradable occupations. Hence, considering putty-clay technology as I do in this paper is particularly relevant for understanding the effects of service offshoring.

3.2 EQUILIBRIUM IN THE OFFSHORING REGIME

A set of wages w_{ij} $i \in [0,1]$, $j = s,u$ fulfills an additional condition in equilibrium relative to the non-offshoring regime. Besides clearing the task markets and fulfilling the zero-profit conditions, the choice of the cutoff traded task I must be cost-minimizing given the wages implied by the set.

[9] Kambourov and Manovskii employ worker-level data on wages and identify workers' occupation and industry switches. In a companion paper, they relate the specificity of human capital to wage changes for the 1969-1997 period.

I will begin with the choice of the cutoff traded tasks. Cost-minimization yields a different cutoff for each skill group whenever the Home-to-RW wages differ across skill levels, as shown in the Appendix. Firms' cost-minimizing decisions are summarized as follows

$$\underset{J_j}{Min}\ MC_j(J_j) = \exp\left\{\left(1-J_j\right)\ln\left(w_{ntj}\right) + \int_0^{J_j} \ln\left(w_j^* \beta t\left(i\right)\right) di\right\} / A, \quad j = s,u, \tag{15}$$

where $J_j \in \left[0,1\right]$ denotes a feasible choice of the cutoff traded task for skill group $j = s,u$, $w_j^* \beta t\left(i\right)$ is the effective import price of task *ij*, and w_{ntj} is the price of a non-offshored task. Note in equation 15 that the wage of all non-offshored tasks having the same skill-intensity is assumed to be the same and the wage of every offshored task is assumed to equal its effective import price. I will show below that wages fulfill these conditions when the task markets is in equilibrium

Based on equation 15, I know that firms will offshore task *ij* if and only if $w_j^* \beta t\left(i\right) < w_{ntj,}\ \ j = s,u$, so that doing so reduces a firm's marginal cost. Thus the equilibrium conditions for the cutoff traded tasks are written as follows

$$w_j^* \beta t\left(I_j\right) = w_{ntj},\ j = s,u, \tag{16}$$

where I_j is the choice of the cutoff traded task that minimizes costs among all feasible choices $J_j \in \left[0,1\right]$. Equation 16 states that cost-minimizing firms are indifferent between offshoring and purchasing the cutoff traded task in the domestic market. This equation and the zero-profit conditions that I address below determine two of the endogenous variables, the wage of non-offshored tasks and the cutoff traded task.

The remaining endogenous variables are the wages of the offshored tasks, which are determined by clearing in the domestic markets of tasks. I will begin with the market of a task that is both offshored and domestically produced. The supply of such a task is inelastic and then fully determines employment in equilibrium. Thus, its employment level is the same as that of the non-offshoring regime because labor cannot be reallocated across tasks. The equilibrium wage of the task equals its effective import price as noted above: at greater domestic wages, firms offshore the task but do not produce it domestically.[10] Intuitively, the effective import price of

[10] When the wage is lower than the task's effective import price, there is an excess demand.

an offshored task summarizes the extent to which the ICT revolution increases its exposure to foreign competition.

The supply of a non-offshored task is inelastic so that its employment level is also the same as that of the non-offshoring regime. The wage is lower than the effective import price; otherwise firms would offshore the task. Because the demands for all non-offshored are symmetric for wages lower than the effective import price, all these tasks have the same wage in equilibrium.[11]

Finally I address the last equilibrium requirement: the zero-profit conditions. These conditions yield, along with cost-minimization, the wage of the non-offshored tasks and the cutoff traded task for each skill group. Equating unit production costs to the effective final goods prices found in the previous section yields the following conditions[12]

$$w_s^* / \tau = \exp\left\{ (1 - J_s)\ln(w_{nts}) + \int_0^{J_s} \ln\left(w_s^* \beta t(i)\right) di \right\} / A, \tag{17}$$

$$\tau w_u^* = \exp\left\{ (1 - J_u)\ln(w_{ntu}) + \int_0^{J_u} \ln\left(w_u^* \beta t(i)\right) di \right\} / A. \tag{18}$$

Equations 17 and 18 implicitly define all vectors (J_j, w_{ntj}) that fulfill the zero-profit conditions. I manipulate these equations to solve for the wage of the non-offshored task and obtain the following expressions

$$w_{nts}(J_s) = \exp\left\{ \ln\left(w_s^*\right) + \frac{\left(\ln(A/\tau) - J_s\ln(\beta) - \int_0^{J_s}\ln\left(t(i)\right)di\right)}{1 - J_s} \right\}, \tag{17'}$$

$$w_{ntu}(J_u) = \exp\left\{ \ln\left(w_u^*\right) + \frac{\ln(A\tau) - J_u\ln(\beta) - \int_0^{J_u}\ln\left(t(i)\right)di}{1 - J_u} \right\}. \tag{18'}$$

I will refer to the wages that appear on the left-hand-sides of equations 17' and 18' as the *zero-profit wages* hereafter. As the cutoff choices equal zero, service offshoring does not occur and the

[11] The demands for the non-offshored tasks are symmetric because the technology displayed in the previous section yields symmetric demand functions. Note also that all non-offshored tasks are supplied in the same amount.

[12] I employ the results from the previous section to write final goods price in terms of RW's wages. The results are still valid because Home is a small country and does not affect either prices or RW's wages.

zero-profit wages collapse to their values from the non-offshoring regime.[13] These wages are increasing in the parameters whose increase reduces costs (e.g. A increases): if the zero-profit conditions hold, the zero-profit wages must increase to restore marginal cost to its original value.

The zero-profit conditions and the cost-minimizing rules solve for the cutoff traded tasks and the wages of the non-offshored tasks. The task-market clearing conditions solve for the wages of the offshored tasks.

3.3 OFFSHORING IMPLICATIONS AND PREDICTIONS

The convex and slightly weighted curve that appears in Figure 1 represents the offshoring cost schedule for the non-offshoring regime.[14] This curve shifts downward as the ICT revolution hits the economy and the value of the shift parameter goes from β_0 to β_1 ($\beta_1 < \beta_0$). I focus on the offshoring regime and refer to the new convex and more heavily weighted curve as "the offshoring cost curve" hereafter. The square-dotted curve depicts the relationship between the zero-profit-to-RW wage w_{ntu} / w_u^* and every feasible choice for the cutoff traded task J_u –equation 18', and its vertical intercept is the Home-to-RW wage from the non-offshoring regime for unskilled tasks–. The circle-dotted curve shows the same relation as the square-dotted for the case of skilled tasks –equation 17'–. The two dotted curves slope upward indicating that greater choices for the cutoff traded tasks generate cost savings that must be compensated for with increases in the wages of the non-offshored tasks (so that profits are zero).

The equilibrium lies at the intersection of the square-dotted and the offshoring cost curves for unskilled tasks, where the choice of the cutoff traded task J_u equals the equilibrium choice –$J_u = I_u^{\tau_0}$–. This cutoff is greater than it is the cutoff traded task for skilled tasks (given by the intersection of the circle-dotted and the offshoring cost curves). The key to this result is the difference between the vertical intercepts of the square- and the circle-dotted curves: as proved in the Appendix, the cutoff traded task is greater for the unskilled tasks whenever the Home-to-RW wage from the non-offshoring regime is greater for unskilled workers. Intuitively, the skilled-abundant country reaps larger savings by offshoring the unskilled tasks because the unskilled to skilled wage is greater there. Hence, the model predicts that skill abundance is relevant to understanding a task's propensity to be offshored based on its skill-intensity. By introducing a

---

[13] More specifically, the zero-profit wages collapse to the wages implied by equations 12 and 13.

[14] Although the offshoring cost function needs to be sufficiently increasing for equilibrium existence, this function does not need to be convex over the whole range of tasks. I assume convexity since this eases the exposition.

role for relative skill abundance, the model reconciles arguments of the traditional factor-proportion models with some aspects of GRH.

Figure 2 depicts equilibrium for a skill-abundant country whose trade costs are greater and given by τ_1 ($\tau_1 > \tau_0$). Comparing Figure 1 to Figure 2 shows the differential impact of service offshoring on two countries with different levels of iceberg costs. The square-dotted curve shifts upward and the circle-dotted curve shifts downward relative to Figure 1: the unskilled to skilled wage is greater, and therefore the difference between the savings caused by the offshoring of the skilled tasks and the offshoring of the unskilled tasks is also greater in Figure 2. Hence, a skill-abundant country with higher iceberg costs offshores a greater set of unskilled tasks and a smaller set of skilled tasks.

In order to obtain predictions for countries with different levels of final goods productivity, it suffices to understand how an increase in this productivity changes the Home-to-RW wages from the non-offshoring regime. In the country with the highest final goods productivity these wages are greater for both skill groups. Service offshoring then causes greater cost savings for the two types of labor so that firms offshore greater sets of both skilled tasks and unskilled tasks.

3.4 Implications for Wages and Predictions

In order to present the wage results, the model builds intuition on the two competing effects exerted by service offshoring: the productivity effect and the foreign competition effect.

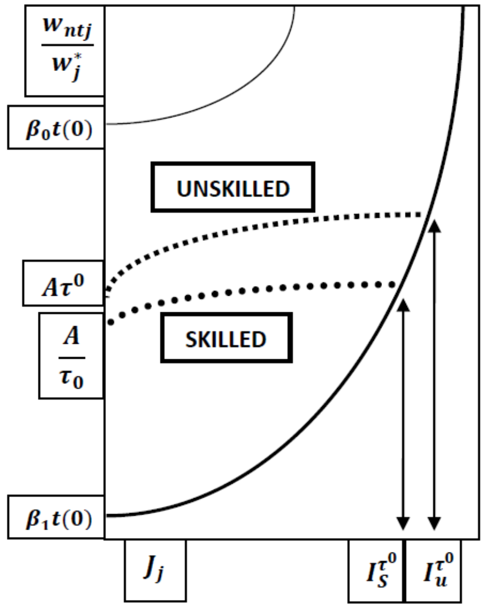
Offshoring allows firms to hire cheaper labor services abroad and therefore generates cost savings that are isomorphic to a productivity increase. The output expansion caused by the productivity increase increases the demand for domestic labor so that offshoring has an increasing effect on domestic wages; I refer to this effect as the productivity effect hereafter.[15,16] On the other hand, exposure to competition from foreign workers increases because tasks produced by domestic workers can be offshored at their effective import prices. Because the wage of an offshored task is never greater than this price in equilibrium, offshoring has a wage-reducing effect which I refer to hereafter as the foreign competition effect.

[15] Over the set of tasks located to the left of the equilibria in Figure 1, the zero-profit wage of a non-offshored task is greater than its effective import price; thus, firms reduce their marginal costs by offshoring these tasks.

[16] Heshmati (2003), Olsen (2006) and Amiti and Wei (2009) approach this effect from an empirical perspective. More recently, Hummels et al. (2011) provides evidence for the existence of this effect.

Figure 1

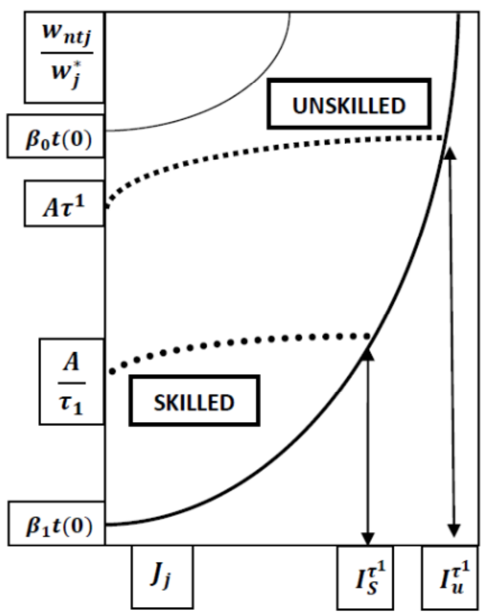
Equilibrium Cutoff Traded Tasks for the Case of Low Trade Costs



Notes: The x-axis shows the choices for the cutoff traded tasks and the y-axis is the zero-profit- to-RW wage ratio.

Figure 2

Equilibrium Cutoff Traded Tasks for the Case of High Trade Costs



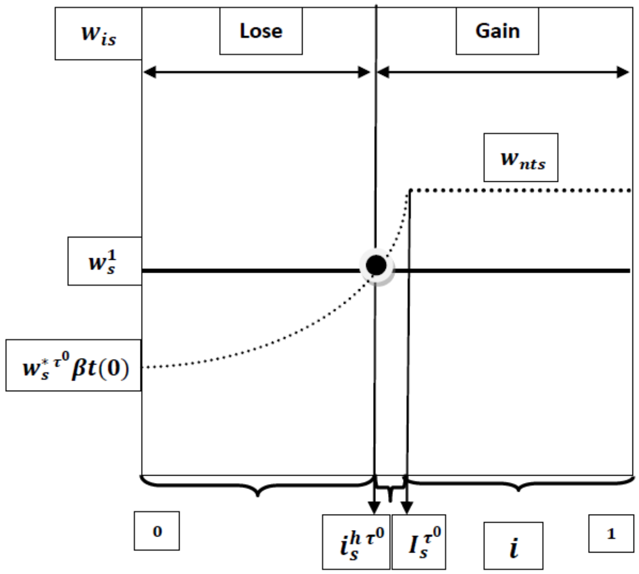
Notes: The x-axis shows the choices for the cutoff traded tasks and the y-axis is the zero-profit- to-RW wage ratio.

The balance between the productivity effect and the foreign competition effect determines a set of workers who lose from service offshoring because their wage decreases (these workers are sometimes referred to as losers) and a set of workers who gain from offshoring (they are sometimes referred to as winners). Figure 3 depicts these sets for the case of skilled labor. The square-dotted curves denote the wage schedule for skilled workers and the horizontal line indicates the wage that these workers receive in the non-offshoring regime. These two curve types intersect at the solid vertical line that identifies the indifferent skilled task i_s^h, for which workers receive the same wage in the offshoring regime as in the non-offshoring regime. Figure 4 shows the corresponding sets for unskilled workers.

Figures 3 and 4 distinguish three types of workers and regions. Workers fulfilling non-offshored tasks are located to the right on the x-axis. These workers gain from service offshoring because their wage increases thanks to the productivity effect. Workers that fulfill the offshored tasks with the lowest offshoring costs are located to the left on the x-axis. Since the offshoring costs of these tasks are low, the ICT revolution increases greatly their exposure to foreign competition. Thus, the foreign competition effect is sufficiently strong that service offshoring decreases the wage of these workers. Finally, workers fulfilling the offshored tasks with the highest offshoring costs are located in the middle regions of the figures. Surprisingly, the wage of these workers increases even though their types of tasks (the same skill-intensity and tradability) are offshored. The reason is that the foreign competition is weaker than the productivity effect.

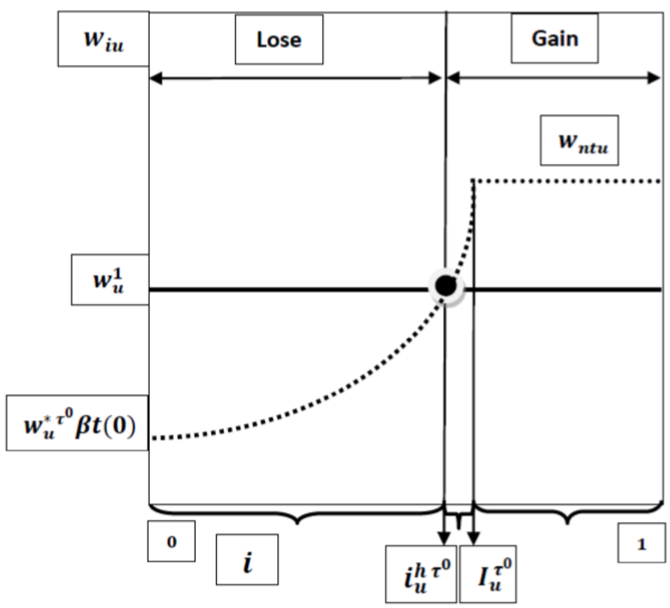
Since the unskilled to skilled wage from the non-offshoring regime is greater in Home, unskilled workers are more exposed to foreign competition than skilled workers. Comparing Figure 3 to Figure 4 shows the differential impact of service offshoring across workers with different skill levels. The proportion of tasks whose wage decreases (*loser tasks*) is greater for unskilled workers than it is for skilled workers. Given tradability, the wage loss of an unskilled loser is greater than that of a skilled loser since her wage decreases by a greater amount (in terms of their wage from the non-offshoring regime). Hence, skill levels are relevant to classifying workers into winners and losers and to quantifying losers' losses.

Figure 3
Schedule of Skilled Wages



Notes: the Figure shows the losers, the winners fulfilling offshored tasks and the winners fulfilling non-offshored tasks.

Figure 4
Schedule of Unskilled Wages



Notes: the Figure shows the losers, the winners fulfilling offshored tasks and the winners fulfilling non-offshored tasks.

The predictions of the model differ in some important ways from the outcomes shown by GRH. Their wage-reducing effect is isomorphic to a labor-supply increase and therefore takes place only when the number of factors is greater than the number of goods. Employing some features of their work and putty-clay technology, I prove the existence of a more general wage-reducing effect which does not depend on the number of factors or the number of goods. Because it is isomorphic to a labor-supply increase, GRH's wage-reducing effect reduces the wage of all tasks having the same skill-intensity by the same amount. Thus, workers are classified into winners and losers (workers whose wage decreases and workers whose wage increases) only on the basis of skill-levels and all losers lose by the same amount, independent of the tradability of their task. In contrast, the extent of my wage-reducing effect increases with tradability so that winners and losers are determined based on skill levels and tradability in my model. Workers fulfilling tasks with sufficiently high offshoring costs gain from offshoring independent of their skill levels so that the typical distributional conflict arising from reductions in the costs of trading goods does not take place. Whereas in GRH the distributional conflict does not take place if the wage-increasing (productivity) effect is greater than the wage-reducing effect, this result holds unambiguously in my model. Furthermore, because the extent of my wage-reducing effect varies smoothly with tradability, some workers gain from offshoring even if their task types are offshored.

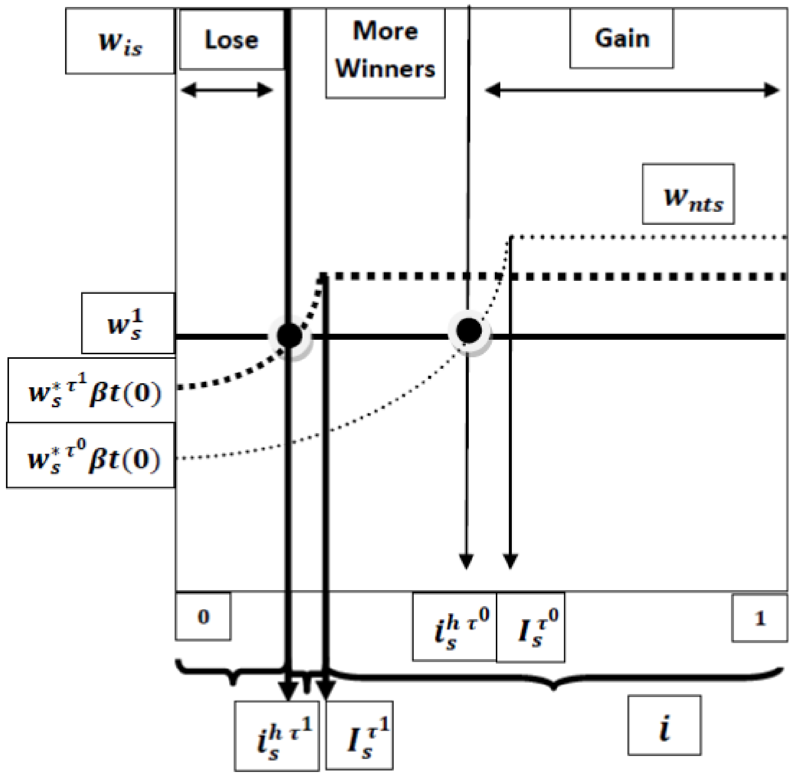
Comparative statics on β shows the effect of ICT improvements.[17] A fall in β reduces the effective import price of the offshored tasks and therefore increases the extent of the foreign competition effect. On the other hand firms reap greater savings so that the improvements increase the extent of the productivity effect. Since ICT improvements increase the extents of the foreign competition and productivity effects, they augment losers' losses and winners' gains. In other words, the improvements generate income redistribution across workers fulfilling tasks with the same skill-intensity but different tradability.[18]

---

[17] These improvements can be interpreted as those that have taken place after the technological revolution.

[18] As the shift parameter goes to zero, all tasks are offshored in the same amount and thus the model converges to a two-good infinite-input world. The wage of every j-skilled task equals the wage received by the j-skilled workers in the RW, so that factor-prices equalize across regions. This result overlaps with the theory of factor-price equalization lenses developed by Deardorff (1994), in which the region of factor price equalization (FPE) becomes the entire factor space as cost equal zero.

Figure 5
Change in the Schedule of Skilled Wages as Trade Costs Increase



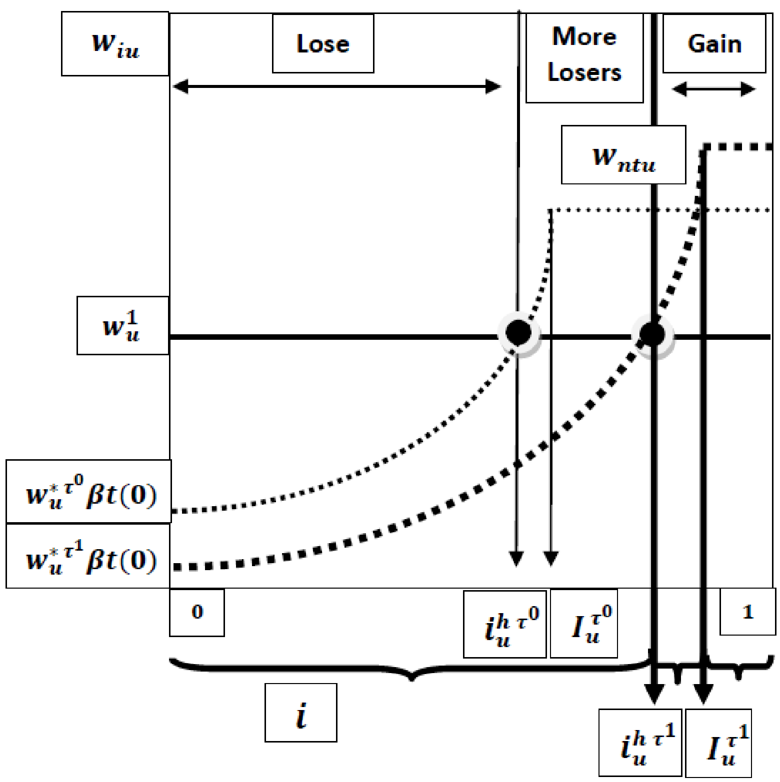
Note: A decrease in Home's wage of skilled worker is isomorphic to a decrease in the same wage for RW.

Comparative statics also shows the differential impact of service offshoring across countries with different levels of iceberg costs. In a country with higher iceberg costs, the skilled wage from the non-offshoring regime is lower and the unskilled wage is higher. Redding and Schott (2003) apply the Stolper-Samuelson theorem to find intuition for this result in a non-offshoring model, arguing that increased remoteness is isomorphic to a reduction in the relative price of the skill-intensive good. The contribution of my model is to prove the existence of second order effects associated with increased remoteness in an offshoring regime. The increase in the unskilled wage from the non-offshoring regime increases the exposure of unskilled workers to foreign competition. By the same token, increased remoteness decreases the exposure of the skilled workers. The Appendix shows that the set of unskilled losers and the wage loss of an unskilled loser increase with iceberg cost, whereas the set of skilled losers and the loss of a skilled loser decrease. Hence, the impacts of service offshoring are more asymmetric across skill levels in a skill-abundant country with higher iceberg costs. Figures 5 and 6 show these results by allowing for changes in RW wages that are isomorphic to the changes in Home's wages mentioned above.

Finally, increases in the final goods productivity increase the sets of loser tasks for unskilled labor and skilled labor. For a given tradability level, a task is more likely to lose from service offshoring in a skill-abundant country with higher final goods productivity. The key to this result is that technological advantage is not diminished by importing tasks.

Comparative statics on the fundamentals of the model yields predictions that are in principle testable with cross-sectional data. Such an econometric excursive would shed light on the differential impact of offshoring on countries with different levels of final goods productivity (TFP levels) and iceberg costs.

Figure 6
Change in the Schedule of Unskilled Wages as Trade Costs Increase



Notes: An increase in Home's wage of unskilled worker is isomorphic to a decrease in same wage for RW.

4 THE RETRAINING PROCESS

This section presents a simple retraining model. Workers that transition to non-offshored tasks receive a higher wage but must retrain to obtain the knowledge that is specific to their new task. The retraining model yields a reallocation of workers across tasks: employment decreases in tasks where retraining occurs and it increases in the non-offshored tasks to which workers transition. The reallocation of workers has no impact on the wage of the non-offshored tasks or the wage of an offshored task since the former wage is determined by the zero-profit conditions and the latter wage is determined by the task-market clearing conditions defined in the previous section.

Workers are heterogeneous in terms of the task they fulfill before the ICT shock and in terms of their ability to retrain. The larger the wage difference between the task a worker fulfills before the ICT shock and a non-offshored task, the more willing she is to retrain. As the wage difference is large, the worker benefits from a larger wage increase by switching tasks. Workers fulfilling task ij are assumed to be distributed based on their ability to retrain and according to a c.d.f. $G(.)$ with support $(\underline{a}, \overline{a})$, where $g(a)$ denotes the proportion of workers fulfilling the task whose productivity is lower than a. The distribution of abilities to retrain is assumed to be identical across tasks.[19]

The retraining decisions are of two types. First, workers decide whether to retrain. Second, workers choose the number of periods their retraining program lasts and the amount of hours they retrain in each period, conditional on retraining. The decision on whether to retrain will arise from the choice of the optimal retraining program because only workers whose optimal retraining plan is sufficiently short will retrain.[20] Thus, I will not address the retraining/non-retraining decision for now and, in order to study the choice of the optimal retraining program, will assume that every worker not fulfilling an offshored task retrains.

Without loss of generality workers' work lives are assumed to equal T periods. To simplify the decision-making process, I follow Ben-Porath's (1967) seminal paper on human capital investment by making the same assumptions:

---

19 If assumed otherwise I should specify a reason for why workers of different characteristics sort across tasks. Such an argument seems far from the scope of this paper and the characteristics of the model: a perfect competition setup where wages equal marginal productivities in equilibrium and homogenous agents that do not expect the ICT shock

20 Retraining is profitable if the program is sufficiently short that there is time to recover the human capital investment.

i. Utility is not a function of activities involving time as an input.

ii. An amount of time per period, normalized to one, is allocated to activities producing earnings and retraining.

iii. Complete asset markets: borrowing and lending happens at a constant rate *r*.

Under these assumptions workers choose their optimal retraining programs by maximizing their lifetime income. The retraining process is completed as a worker *produces* θ hours of effective learning, which she trades for actual hours employing a CES learning technology. Thus, a worker who has a retraining productivity level equal to a and fulfills the ij task solves the following constrained optimization problem

(19)
$$\underset{R_{ij}^{a},\left\{h_{i,j,t}^{a}\right\}_{0}^{R_{ij}^{a}}}{Max} I_{ij}^{a,\mathrm{Ret}}$$

s.t.
$$Q_{ij} = a\left[\int_{0}^{R_{i,j}^{a}} \left(h_{ij,t}^{a}\right)^{\rho} dt\right]^{\frac{1}{\rho}} = \theta,$$

where

$$I_{ij}^{a,\,Ret} = \int_{0}^{R_{ij}^{a}} \left(1 - h_{ij,t}^{a}\right) w_{j}^{*} \beta t(i) \exp\{-rt\} dt + \int_{R_{ij}^{a}}^{T} w_{ntj} \exp\{-rt\} dt.$$

is the worker's lifetime income under the retraining option, $h_{ij,t}^{a}$ is the amount of hours she retrains in period t, R_{ij}^{a} is the amount of periods her retraining program lasts (the program's duration), Q_{ij} denotes the worker's production of effective learning hours and $\rho < 1$ measures the sensitivity of the learning process to the program's duration. In the CES specification the elasticity of substitution is less than infinite, so workers become less productive after a long learning session (the marginal productivity of actual hours decreases). Like in any learning process, actual hours are more productive when spread out: knowledge is better assimilated over time and thus *crammers* need a greater amount of hours to complete retraining. Hence, choosing a short retraining program is more costly in terms of total hours.

Each worker faces an additional time constraint limiting the duration of her retraining program because no program lasts longer than T periods (the worker's lifetime). Instead of adding this time constraint to the optimization problem, I will impose the constraint on the solution arising from the one-constraint problem shown in 19.

I will then proceed by solving 19 in two steps. I will solve for the optimal set of hours and the marginal cost of effective hours given the program's duration, and I will then plug the solution into 19 to solve for that duration. Equation 20 shows the result of the first step of the optimization process

$$\lambda_{ij}^{a^*} = \frac{w_j^* \beta t(i)}{a}\left(\left(\frac{1-\rho}{r\rho}\right)\left(\exp\left\{\frac{r\rho R_{ij}^a}{1-\rho}\right\}-1\right)\right)^{-\left(\frac{1-\rho}{\rho}\right)}. \tag{20}$$

where $\lambda_{i,j}^{a^*}$ is the marginal cost of an effective learning hour. The cost decreases with the program's duration, indicating that short retraining programs are more costly because crammers need a greater amount of hours to complete retraining. Plugging 20 and the optimal set of hours into the lifetime income definition shown in 19 yields the expression that I maximize to obtain the optimal program's duration. The following condition characterizes the duration

$$\left(w_{ntj} - w_j^* \beta t(i)\right)\exp\left\{-R_{ij}^a\right\} = \left(\frac{\theta w_j^* \beta t(i)}{a}\right) r^{\frac{1}{\rho}} \left(\frac{1-\rho}{\rho}\right)^{-\left(\frac{1-\rho}{\rho}\right)} \exp\left\{\frac{r\rho R_{ij}^a}{1-\rho}\right\}\left(\exp\left\{\frac{r\rho R_{ij}^a}{1-\rho}\right\}-1\right)^{-\frac{1}{\rho}}. \tag{21}$$

The LHS of equation 21 shows the marginal benefit from decreasing the duration of the program: the worker completes retraining and therefore benefits from the wage increase earlier. The wage increase is sufficiently small for some workers that their retraining programs are chosen to be perpetual and no real value of R_{ij}^a solves for equation 21. These workers fulfill the least tradable tasks and are more likely to fulfill skilled tasks.[21] If they did not face a time constraint, they would choose a perpetual program to minimize retraining costs. I impose the time constraint so that the duration of these workers' programs equals T periods.[22]

[21] Note that the service offshoring has increased the wage of some of these workers.

[22] A retraining programs lasting T period is these workers' optimal strategy as shown in the Appendix.

The marginal benefit from decreasing the program's duration determines, along with the marginal cost –the RHS of equation 21–, the duration for the remaining workers. The optimal duration that arises from the trade-off is written as follows

$$
\text{(22)} \qquad R_{ij}^{a^*} = T; \qquad if \;\; B_{ij}^{a^*} = -\left(\frac{1-\rho}{r\rho}\right)\ln\left(1-\frac{r^{\frac{1}{\rho}}\left(\frac{\rho}{1-\rho}\right)^{1-\rho}}{\left(\frac{a}{\theta}\left(\frac{w_{ntj}}{w_j^*\beta t(i)}-1\right)\right)^{\rho}}\right) \geq T,
$$

$$
R_{ij}^{a^*} = B_{ij}^{a^*}; \qquad\qquad \textit{Otherwise}.
$$

I have imposed the time constraint so that the duration of the retraining programs that appear in the second line in statement 22 equals T periods.[23] The first line in this statement corresponds to workers whose retraining programs are optimally chosen to last shorter than T periods. The duration of these programs is smaller, the more tradable the task or the lower the skill level. Service offshoring decreases the wage of the unskilled tasks and the most tradable tasks by a greater amount, and therefore workers fulfilling these tasks benefit from a higher wage increase by retraining. Since they benefit from a higher wage increase, these workers choose short retraining programs so that start to benefit from this increase earlier. Hence, workers fulfilling the most tradable tasks and the unskilled tasks choose a shorter retraining program given the level of retraining productivity.

The schedule of optimal retraining programs shown in equation 22 yields the retraining-non retraining decision since only workers choosing short retraining programs retrain. Specifically, a worker retrains if and only if the discounted value of her lifetime income is greater under the retraining option than it is under the non-retraining option. The lifetime income difference between the two options is written as follows

$$
\text{(23)} \qquad I_{ij}^{a,Ret} - I_{ij}^{a,NRet} = \left(\frac{w_{ntj} - w_j^*\beta t(i)}{r}\right)\left(e^{-R_{ij}^{a^*}\left(\frac{r\rho}{1-\rho}\right)} - e^{-rT}\right),
$$

[23] The Appendix shows that choosing a retraining program lasting T periods is these workers' optimal strategy.

where $I_{i,j}^{a^h,NRet}$ is the worker's lifetime income under the non-retraining option. The income difference decreases monotonically with the program's duration and therefore the worker retrains when the following condition holds

$$R_{ij}^{a^*} < T(1-\rho).\qquad (24)$$ [24]

where a^* denotes the cutoff level of retraining productivity for which a worker fulfilling task ij retrains. A worker retrains when her retraining program is sufficiently short that her post-retraining period allows her to recover the investment associated with retraining. Since workers fulfilling the most tradable tasks and the unskilled tasks choose a shorter retraining program, the cutoff level of a is smaller for these tasks.[25]

Retraining occurs in the tasks where (at least) the worker with the highest ability to retrain does so. There exists a retraining cutoff task that defines the set of tasks where retraining occurs since a worker's willingness to retrain decreases monotonically with her task's offshoring costs. Employing equation 25, I solve for this retraining cutoff task

$$R_{\overline{I_j}}^{\bar{a}^*} = T(1-\rho).\qquad (25)$$

where $\overline{I_j}$ is the j-skilled retraining cutoff task. The Appendix shows that the retraining cutoff task is greater for unskilled labor than it is for skilled labor (given tradability), meaning that the proportion of tasks where retraining occurs is greater for the unskilled tasks. Intuitively, the unskilled workers are more willing to retrain because service offshoring decreases their wage by a greater amount.

5 PREDICTIONS AND MATCHING WITH CURRENT AND FURTHER EMPIRICAL EVIDENCE

This section shows that the employment predictions, the wage results and the outcomes on rates of occupation switching are consistent with the emerging empirical literature. The relation between the employment predictions and the wage result are also consistent with this literature.

[24] Note that any worker whose plan is forced to last T periods will not retrain; the tasks of these workers must have sufficiently high offshoring costs.

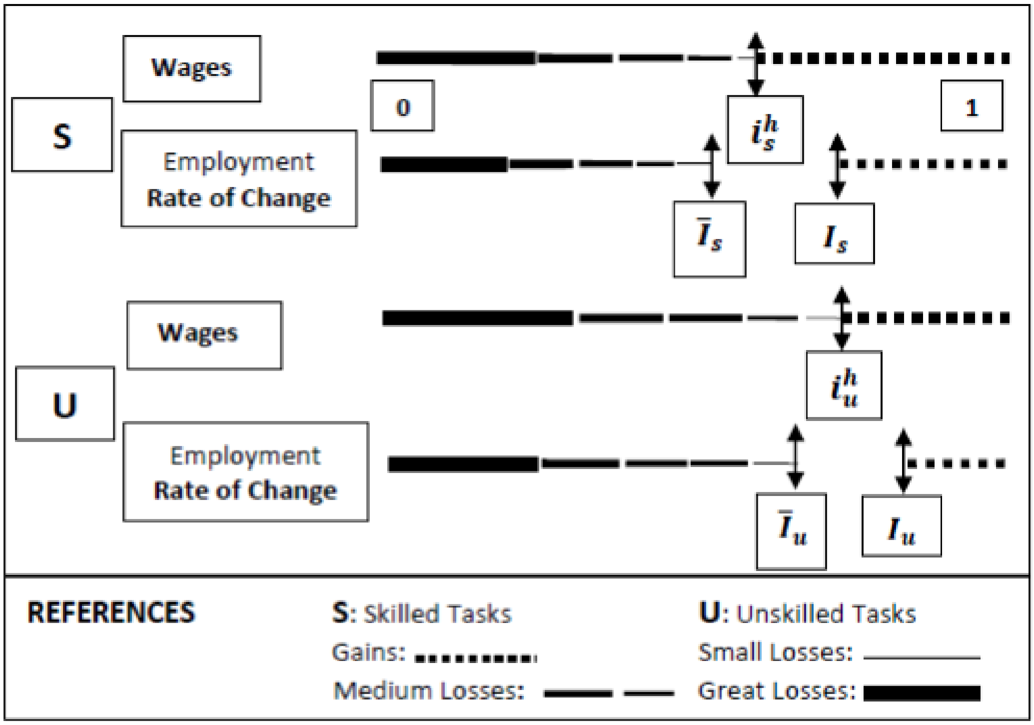
[25] A lower level cutoff level of a implies that the employment decrease is greater as noted in the following section.

Figure 7 summarizes the employment predictions of the model. The sets of tasks where employment increases comprise the least tradable tasks; they are indicated with the square dotted lines and located to the right of the cutoff traded tasks on the continuums labeled *Employment*. The sets of tasks where employment decreases comprise the most tradable tasks, they are indicated with solid lines and located to the left of the retraining cutoff task on the continuums. Within these sets of tasks the extent and the rate of employment decrease differs. The most tradable tasks have lower cutoff levels of a and therefore greater rates of employment decrease, as denoted by heavier solid lines as we move left on Figure 7. Hence, service offshoring reallocates employment based on the degree of tradability of the tasks. These predictions are consistent with Blinder (2006, 2009), Baldwin (2006) and Grossman and Rossi-Hansberg (2006, 2008) which have emphasized the importance of tradability to understanding the impacts of service offshoring.

On the other hand, the model keeps the role traditionally assigned to skill-intensity: the set of tasks where employment increases is larger for the skilled tasks than it is for the unskilled tasks, as indicated by the larger square dotted line on the uppermost continuum. By the same token, the rate of employment decrease is greater in the unskilled tasks given tradability. Because skill-intensity and tradability are jointly relevant to understanding the employment effects of service offshoring, the predictions of the model are also consistent with Crinò (2009, 2010). His evidence shows that the probability that employment increases is increasing in the skill-intensity of a task, given tradability. Furthermore, this probability also decreases in tradability, given skill-intensity.

The model yields predictions about the impact of service offshoring on rates of occupation switching. Switching rates increase by more for unskilled workers than do for skilled workers because retraining is more frequent among the unskilled tasks. This prediction is consistent with the evidence presented by Liu and Trefler (2011), whose data suggest a greater probability of switching for unskilled workers. Furthermore, the same evidence suggests that the impact of service offshoring on switching rates is gradual. My model predicts a gradual impact on switching rates since occupation switching is driven by the length of workers' retraining programs.

Figure 7
Employment and Wage Predictions



Notes: The wage and employment impacts of service offshoring depend on the skill-intensity and tradability of a task.

Figure 7 also depicts the wage predictions of the model. The likelihood of finding a loser from service offshoring is greater the more tradable the task or the lower the skill level. Wage losses are greater for the unskilled losers given tradability so skill levels become relevant. Tradability is also relevant because the sets of losers and winners are not fully determined by skill levels. In this regard, the model is consistent with Hummels et al. (2011) which argues that both tradability and skill-intensity determine the response of an occupation to service offshoring.

The model predicts a positive correlation between changes wages and employment at the task-occupational and therefore is also consistent with another piece of evidence provided by Crinò (2010). As noted by him, the correlation is positive whenever the changes in employment and wages are generated by demand shocks.

Finally, the model yields predictions based on a country's levels of trade costs and final goods productivity. Offshoring should increase employment in a greater proportion of unskilled tasks and a lower proportion of skilled tasks in countries with higher trade costs. In these countries the proportion of tasks where wages increase is higher for skilled tasks and the proportion of tasks where wages fall is higher for unskilled tasks. The model also predicts that an unskilled worker's loss is greater if the worker's country is more isolated from the RW. Countries with higher final goods productivities have more losers who suffer from greater losses as a result of offshoring. To the best of my knowledge there is no empirical study comparing the impacts of service offshoring across countries.

6 CONCLUSIONS

The impacts of service offshoring on the wage and the employment level of a task (occupation) depend on its degree of tradability. The more tradable a task is, the more service offshoring increases its exposure to the competition of foreign workers. Whereas wages and employment decrease by a greater amount in tasks that are more exposed to foreign competition, wages and employment increase in the least tradable tasks (even though these tasks are offshored). Skill-intensities are also relevant to offshoring propensity since relative wages differ across regions and therefore the unskilled tasks are more exposed to foreign competition in a skill-abundant country. By the same token, wage loss and employment reallocation are greater among the unskilled tasks.

The paper highlights the relevance of tradability to understanding the effects of the ICT revolution. Technological improvements have changed the nature of international competition by reducing the offshoring costs of labor tasks. International competition seems to be occurring at a much finer level of disaggregation currently, causing tradability to play an important role. Tradability is expected to play an important role in determining the effects of increasing trade as labor tasks are of varying natures: tasks differ in their degrees of complexity, their requirements for personal interaction, their routineness, and their ease of understanding by foreign workers. Thus we expect the ICT revolution to have a varying impact on offshoring costs and a varying impact on the wages and the employment of these tasks. Besides being intuitively relevant, tradability has been claimed as relevant by several authors.

Standard international trade theory has traditionally classified labor into skill groups. Although this classification is relevant to understanding the impacts of service offshoring, it has become insufficient because the emerging empirical literature seems to suggest that the wage and employment impacts vary within skill groups. The paper suggests that the change in the nature of international competition will make it necessary to look at additional job characteristics in order to provide new labor classifications. The paper also opens lines for further empirical research. It proposes cross-sectional predictions for countries with different characteristics that have not been investigated in the literature; later empirical research could address these predictions using applicable data. On the other hand, data availability represents a major constraint hampering investigation of the effects of the ICT revolution on developing countries. Apropos of developing countries, it would be particularly interesting to investigate whether their wage behavior follows the logic proposed in this paper. The ICT revolution might have increased service exports and thus the wages of the most tradable tasks in such countries as India or China, as suggested by anecdotal evidence. Ultimately, this is an empirical question.

7 APPENDIX

7.1 THE LARGE COUNTRY CASE

I study the case of a large country and solve for domestic wages in terms of labor endowments, technologies and transportation costs. The market of the skill-intensive good is in equilibrium as Home's excess supply equals RW's excess demand augmented by transport. Assuming that consumers have identical Cobb-Douglas preferences, this market-clearing condition is written as follows

$$AL_s - \frac{\alpha \mathrm{Y}}{p^T} = \tau\left(\frac{\alpha \mathrm{Y}^*}{\tau p^T} - L_s^*\right),$$

where $\mathrm{Y} = \mathrm{A}(p^T L_s + \tau L_u)$ and $\mathrm{Y}^* = \tau p^T L_s^* + L_u^*$ are Home's and RW's incomes, respectively. Employing market clearing and the zero-profit conditions I obtain domestic wages, which are written as follows

$$w_u = A\tau; \quad w_s = A\left(\frac{\alpha}{1-\alpha}\right)\left(\frac{A\tau L_u + L_u^*}{AL_s + \tau L_s^*}\right).$$

7.2 DIFFERENT CUTOFF TRADED TASKS ACROSS SKILL GROUPS

Let's consider the following expressions for $\dfrac{w_{ntj}\left(J_j = I_u\right)}{w_j^* \beta t\left(J_j = I_u\right)}$

$$\frac{w_{ntu}(I_u)}{w_u^*\beta t(I_u)} = \exp\left\{\frac{\ln\left(w_u / \mathrm{w}_\mathrm{u}^*\right) - \ln(\beta) - \int_0^{I_u}\ln\left(t(i)\right)di}{1-I_u}\right\} = 1,$$

$$\frac{w_{nts}(I_u)}{w_s^*\beta t(I_u)} = \exp\left\{\frac{\ln\left(w_s / \mathrm{w}_\mathrm{s}^*\right) - \ln(\beta) - \int_0^{I_u}\ln\left(t(i)\right)di}{1-I_u}\right\} < 1,$$

where the first equality indicates that I_u is the unskilled cutoff traded task. If $\frac{w_u}{w_u^*} > \frac{w_s}{w_s^*}$ then $\frac{w_{nts}(I_u)}{w_s^*\beta t(I_u)} < 1$, and therefore $\frac{w_{nts}(J_s)}{w_s^*\beta t(J_s)}$ must increase to reach one in equilibrium. Finally, note that

(A.1) $$\frac{d\left(\frac{w_{nts}(J_s)}{w_s^*\beta t(J_s)}\right)}{dJ_s} = \frac{w_{nts}(J_s)}{w_s^*\beta t(J_s)}\left[\frac{\ln\left(\frac{w_{nts}(J_s)}{w_s^*\beta t(J_s)}\right)}{1-J_s} - \frac{t'(J_s)}{t(J_s)}\right] < 0 \text{ at } J_s = I_u .$$

The expression t is negative for any $J_s \geq I_u$. Hence, $I_u > I_s$ if $\frac{w_u}{w_u^*} > \frac{w_s}{w_s^*}$.

7.3 Comparative Statics

I employ 17', 18' and A.1 to obtain the following results

$$\frac{dI_j}{d\tau} = -\frac{\left(\frac{d\left(\frac{w_{ntj}(J_j)}{w_j^*\beta t(J_j)}\right)}{d\tau}\right)_{J_j=I_j}}{\left(\frac{d\left(\frac{w_{ntj}(J_j)}{w_j^*\beta t(J_j)}\right)}{dj_j}\right)_{J_j=I_j}}.$$

Whereas the numerator is negative for the case of skilled tasks, it is positive for the case of unskilled tasks. This proves that $\frac{dI_s}{d\tau} < 0$ and $\frac{dI_u}{d\tau} > 0$ given that denominator is negative for both cases.

The following expression studies the effect of changes in the Hicks parameter

$$\frac{dI_j}{d\tau}=-\frac{dI_j}{dA}=-\frac{\left(\frac{d\left(\frac{w_{ntj}\left(J_j\right)}{w_j^*\beta t\left(J_j\right)}\right)}{dA}\right)_{J_j=I_j}}{\left(\frac{d\left(\frac{w_{ntj}\left(J_j\right)}{w_j^*\beta t\left(J_j\right)}\right)}{dj_j}\right)_{J_j=I_j}}.$$

The numerator is negative and the denominator is negative for both cases. Hence, $\frac{dI_s}{dA}>0$ and $\frac{dI_u}{dA}>0$.

7.4 Winners and Losers from Service Offshoring

The indifferent task, which has been indicated by *h*, is written as follows

$$\frac{w_j}{w_j^*\beta}=\beta t\left(i_j^h\right).$$

If $\frac{w_u}{w_u^*}>\frac{w_s}{w_s^*}$ and $t(.)$ is increasing in i, then $i_s^h<i_u^h$.

7.5 Retraining Programs Longer than *T*

Consider the first order condition of the unconstrained problem, and note that the marginal net benefit from increasing the duration of the program is as follows

$$\left(\frac{\theta w_j^*\beta t(i)}{a}\right)r^{\frac{1}{\rho}}\left(\frac{1-\rho}{\rho}\right)^{-\left(\frac{1-\rho}{\rho}\right)}\left(1-\exp\left\{\frac{-rR_{ij}^a}{1-\rho}\right\}\right)^{-\frac{1}{\rho}}-\exp\left\{-rR_{ij}^a\right\}\left(w_{ntj}-w_j^*\beta t(i)\right).$$

The two terms are monotonically decreasing in R_{ij}^{a} and therefore the marginal benefit is positive for $R_{ij}^{\mathrm{a}}<R_{i,j}^{\mathrm{a}}$. The worker increases the program's duration as much as he can. Hence, her best strategy is to set the duration to T periods.

7.6 CUTOFF RETRAINING TASKS

Replacing the optimal plan's duration in equation 25 yields the following

$$I_j = t'\left[\left(\frac{w_{ntj}}{w_j^*\beta}\right)\left(\frac{\left(\frac{\overline{a}}{\theta}(1+e^{Tr\rho})\right)^{\frac{1}{\rho}}}{\left(\frac{\overline{a}}{\theta}(1+e^{Tr\rho})\right)^{\frac{1}{\rho}}+r^{\frac{1}{\rho}}\left(\frac{\rho}{1-\rho}\right)^{\frac{1-\rho}{\rho}}}\right)\right].$$

This retraining cutoff increases in the zero-profit to RW wage ratio and therefore is greater for the unskilled tasks.

8 REFERENCES

Acemoglu, Daron (2003), "Patterns of Skill Premia," *Review of Economic Studies*, 70 (2): 199-230.

Acemoglu, Daron, Pol Antràs, and Elhanan Helpman (2007), "Contracts and Technology Adoption," *American Economic Review* , 97(3): 916-943.

Amiti, Mary, and Shang-Jin Wei (2005), "Fear of Service Outsourcing: Is It Justified?: Evidence from the United States," *Economic Policy*, 20(42): 308-347.

Amiti, Mary, and Shang-Jin Wei (2009), "Service Offshoring and Productivity: Evidence from the United States," *The World Economy,* Wiley Blackwell, 32(2): 203-220.

Baldwin, Richard (2006), "Globalisation: The Great Unbundling(s)," Paper for the Finnish Prime Minister's Office, Economic Council of Finland as part of EU Presidency, September.

Ben-Porath, Yoram (1967), "The Production of Human Capital and the Life Cycle of Earnings," *The Journal of Political Economy*, 75(4): 352-65.

Blinder, Alan S. (2009), "Offshoring: The Next Industrial Revolution," *Foreign Affairs,* 85(3): 113-128.

Blinder, Alan S. (2010), "How Many US Jobs Might Be Offshorable?," *World Economics,* 10(2): 41-78.

Crinò, Rosario (2009), "Offshoring, Multinationals and Labour Market: A Review of the Empirical Literature," *Journal of Economic Surveys*, 23(2): 197-249.

Crinò, Rosario (2010), "Service Offshoring and White Collar Employment," *Review of Economic Studies*, 77(2): 595-632.

Deardorff, Alan V. (1994), "The Possibility of Factor Price Equalization, Revisited," *Journal of International Economics*, 36(1): 167-175.

Mankiw, Gregory N., and Patrick Swagel (2006), "The Politics and Economics of Offshore Outsourcing," *Journal of Monetary Economics*, 53 (5): 1027-1056.

Grossman, Gene. M., and Esteban Rossi-Hansberg (2006), "The Rise of Offshoring: It's Not Wine for Cloth Anymore," *The New Economic Geography: Effects and Policy Implications*, ed. Federal Reserve Bank of Kansas City, pp 59-102.

Grossman, Gene. M., and Esteban Rossi-Hansberg (2008), "Trading Tasks: A Simple Theory of Offshoring," *American Economic Review*, 98(5): 1978-1997.

Heshmati, Almas (2003), "Productivity Growth, Efficiency and Outsourcing in Manufacturing and Service Industries," *Journal of Economic Surveys*,17(1): 79-112.

Hummels, David, Rasmus Jorgensen, Jakob R. Munch, and Chong Xiang (2011), "The Wage and Employment Effects of Offshoring: Evidence from Danish Matched Worker-Firm Data," *Working Paper* 17496, NBER , <http://www.nber.org/papers/w17496>.

Kambourov, G., and I. Manovskii (2009), "Occupational Mobility and Wage Inequality," *Review of Economic Studies*, 76(2): 731-759.

Kambourov, G., and I. Manovskii (2009), "Occupational Specificity of Human Capital," *International Economic Review*, 50(1): 63-115.

Krugman, P. (2011), "Degrees and Dollars," *New York Times* , March 6, 2011.

Liu, R., and D. Trefler (2011), "A Sorted Tale of Globalization: White Collar Jobs and the Rise of Service Offshoring," *Working Paper* 17559, NBER, <http://www.nber.org/papers/w17559>.

Olsen, K. B. (2006), "Productivity Impacts of Offshoring and Outsourcing: A Review," *Working Paper* 2006/1, Directorate for Science, Technology and Industry (STI), OECD, Paris and Washington D. C.

Psacharopoulos, G. (1994), "Returns to Investment in Education: A Global Update," *World Development*, 22(9): 1325-1343.

Redding, S., and P. K. Schott (2003), "Distance, Skill Deepening and Development: Will Peripheral Countries Ever Get Rich?," *Journal of Development Economics*, 72(2): 515-541.

Ritter, M. (2008), *Offshoring, Trade in Tasks and Occupational Specificity of Human Capital,* manuscript, Temple University.

Samuelson, P. A. (1952), "The Transfer Problem and Transport Costs: The Terms of Trade When Impediments are Absent," *The Economic Journal*, 62(246): 278-304.

Trefler, D. (2006), "Policy Responses to the New Offshoring: Think Globally, Invest Locally", *Working Paper Series* 2006-1, Industry Canada.

CENTER FOR LATIN AMERICAN MONETARY STUDIES
Regional Association of Central Banks

www.cemla.org