A Model Of Employment And Wage Impacts Of Service Offshoring

Martin Tobal*

UCSD

Abstract

I develop a two-sector model of trade in final goods and intermediate tasks (services). Goods differ in skill intensity and tasks differ in tradability. A country with high final goods productivity and abundant skilled labor relative to the rest of the world is shown to have incentives to import (offshore) both skilled and unskilled tasks that are greater for the latter. Consequently, given identical tradability schedules, more unskilled than skilled tasks are imported in equilibrium. With putty-clay technology for tasks that locks workers into occupations in the short run but allows retraining in the long run, transition from the non-offshoring to the offshoring equilibrium yields employment and real wage effects in line with the young empirical literature on service offshoring: both effects increase from negative to positive as tradeability declines, with the switches from negative to positive occurring at a higher level of tradeability for skilled than unskilled tasks. More productive countries will have more losers because they offshore more tasks.

*I am deeply thankful to James Rauch for his appreciable advice and his inestimable support. I am also particularly grateful to Prof. Gordon Hanson. I thank Thomas Baranga, Marc Muendler and other attendants to UCSD seminars for valuable comments. I appreciate the funding provided by Fundacion ICO, Gobierno de España. E-mail correspondence: mtobal@ucsd.edu.

1 Introduction And Motivation

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 abupt service offshoring increase documented by Amiti and Wei [3][4], Crino [9], and Treffler [30]. The service offshoring boom has received increasing attention in the media and from academic research in recent years.[1]

Researchers disagree about which characteristics of a task determine its propensity to be offshored. Ultimately, the answer to this debate will determine the natures of the jobs and the income that are or will potentially be lost to service offshoring. I develop a service offshoring model that serves as a basis to investigate wage and employment impacts for a country with high final goods productivity and abundant skilled 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 have different tradability. In modeling tradability, I follow Grossman and Rossi-Hansberg [15] (henceforth GRH); I consider offshoring costs that are common to all tasks, which I denote with a shift-parameter, and offshoring costs that are specific to the tasks, which I denote with a tradability index.[2]In this setup a task's propensity to be offshored depends on two labor dimensions, skill intensity and tradability.[3]

I identify a cutoff traded task for each skill intensity, below which tasks are offshored due to low tradability costs and above which tasks are produced domestically. The cutoff traded tasks are different for skilled and unskilled labor, with more of the latter tasks imported. In generating a greater cutoff task for unskilled labor, I rely on a standard factor proportion argument: the skilled relative wage is lower in the skill-abundant country and therefore firms will offshore more unskilled tasks.[4]In contrast, the explanation of GRH for different skilled and unskilled cutoffs is based on a potential correlation between offshoring costs and skill groups (different shift parameters across skill groups).[5]

The two labor dimensions are not just important for offshoring propensity; they also determine the wage response of a task. In generating wage responses, I rely on the putty-clay assumption under which knowledge is task-specific and thus the labor putty that hardens into task-clay is immobile. The ICT shock then shifts the demands for tasks, impacting only wages in the short-run. Because the extent of the demand shifts varies depending on the tradability of the tasks, the wages of tasks with different

[1]For the U.S., Mankiw and Swagel [14] show that service offshoring received much political and media attention in the presidential elections of 2004.

[2]Production in the two GRH sectors involves a continuum of H tasks, intensive in skilled labor, and L tasks, intensive in unskilled labor.

[3]Blinder [8] builds a subjective index of tradability based on whether occupations require face-to-face interaction. Jensen and Kletzer define tradeable occupations as those that are geographically concentrated.

[4]A large literature relates offshoring to the skill dimension of labor. See Bhagwati et *al.* [7], Deardorff [13], Treffler [29], Kohler [22] and Basco [11] for some examples of this literature.

[5]The empirical literature remains divided about whether such a correlation between skill intensity and tradability exists. Whereas Blinder [8] finds little or no correlation between offshorability and skill intensity, Jensen and Kletzer [19] find that workers in tradable sectors have higher skills.

tradability will respond differently to the ICT shock. Unlike GRH, my model then predicts that winners are not fully determined by skill-level, which reflects the intuitive idea that although radiologists and physicians spend the same time at school, they should not be equally affected by service offshoring. Furthermore, skill-levels are still relevant for determining wages in my model. Along this line, I show that service offshoring creates more losers among unskilled workers and more winners among skilled employees.

The wage results of my model find some empirical support in an emerging literature, which suggests that both tradabilty and skill intensity are relevant for explaining wage changes. Hummels et *al.* [17] study the impact of offshoring on Danish wages for the 1995-2006 period. Employing matched worker-firm data, the authors show that offshoring tends to increase the high-skilled wage and decrease the low-skilled wage. Hummels et *al.* find that workers whose occupations involve routine tasks (more tradable tasks) suffer from larger wage falls. Crino [10] also highlights the relevance of the two labor dimensions for determining wage responses. The author finds that changes in occupational wages are positively correlated with changes in occupational employment, even after controlling for variations in the occupational supply (given Crino's results on employment described below, this correlation indicates that wages have increased in skilled low-tradability occupations).

Although service offshoring harms the low-tradability tasks, not every worker fulfilling a traded task is harmed by offshoring. The reason is that, as in GRH, service offshoring increases the productivity of domestic firms and therefore increases the demand for labor and domestic wages in my model. I also identify an offshoring effect that reduces domestic wages that I already described, which I call the foreign competition effect. The productivity and foreign competition effects yield an innovative result in my model: some workers benefit from service offshoring, even though tasks of their type are offshored.

Perceiving a higher wage in the non-offshored tasks, some workers in my model quit the offshored tasks, driving the employment responses. These workers must undergo a retraining process to acquire additional specific knowledge and thereby switch to the non-offshored tasks. Retraining entails time and monetary costs, so that only workers whose gains are sufficiently large will retrain. My model allows retraining abilities to differ across workers. However, when linking retraining decisions to employment responses, I assume that the retraining abilities are identically distributed across tasks (this assumption requires that workers do not expect the ICT revolution). Under this assumption, retraining decisions and thus employment responses only differ across tasks because service offshoring harms workers' wages by different amounts. Workers fulfilling more offshorable tasks are harmed more and thus are more willing to retrain and benefit from a larger wage increase. Therefore, retraining is more frequent in more offshorable tasks. It follows that, unlike GRH, my model yields different employment responses within the set offshored tasks. Moreover, these employment responses vary smoothly with respect to the tradability of the tasks because the wage decrease caused by service offshoring decreases smoothly with the tradability index.

This paper also contributes to the literature on service offshoring through comparative statics exercises that yield cross-sectional predictions for countries with different characteristics. In particular, the paper compares offshoring effects across countries with different degrees of technological advantage (more productive) and different levels of trade isolation (higher transport costs on goods). The comparative statics show that isolation magnifies the asymmetry of the offshoring effect across skill groups. In other words, there are more skilled winners and more unskilled losers in countries with higher trade costs. Moreover, these countries offshore more unskilled tasks but fewer skilled tasks than nations that are more open to trade (in goods). The comparative statics also show that a higher productivity in final goods raises wages but creates more losers and more tasks offshored due to service offshoring. The key to this result is that technological advantage is not diminished by importing tasks.

The smoothness of the employment responses makes the predictions of this model more easily testable from an empirical perspective. The employment results of this paper connect to the most recent advances of a still young empirical literature, particularly to Crino (2010). Crino jointly investigates the roles of skill intensity and tradability by studying the effect of service offshoring on the U.S. white-collar population with a sample composed of 112 occupations and of 144 industries for the 1997-2006 period. The author lets service offshoring act as a shifter in his formulation of occupational-demands and estimates elasticities with respect to the shifter. Crino finds that the positive elasticities are concentrated among skilled occupations and that the negative elasticities are concentrated among unskilled occupations. Furthermore, he constructs a tradability index based on job characteristics and estimates the probability of finding a positive employment response. This probability increases with an occupation's skill intensity, given offshorability, and decreases with its tradability index, given skill intensity. In section 5, I show that this paper rationalizes the empirical evidence provided by Crino. Hence, this paper also contributes to the literature by yielding employment responses that are appropiate for the use of further empirical research and by rationalizing existing results.

To isolate the effects of service offshoring, I simulate the ICT revolution with an abrupt reduction in the offshoring costs of the tasks, which divides my analysis into two regimes. The first regime represents the pre-revolution period, and the second regime represents the period after ICT shock. I present the first regime in section 2, in which I allow only for trade in goods. In section 3, I allow for trade in tasks and obtain offshoring results and wage responses at the task level. I introduce the retraining model in section 4, and I use this model along with the wage responses to obtain employment results. I summarize the employment results and compare them to some of the literature's empirical findings in section 5. Section 6 concludes and Appendix 1 proposes a discussion about the new role of public policy in an ICT-world.

2 Trade In Goods

I develop a task-based model of two goods and two factors. I use the model to study the pre-revolution period, in which offshoring costs are sufficiently high that firms do not import tasks. Therefore, countries only trade goods and firms only decide on how much of each domestically produced task to purchase. Domestic workers decide which task to fulfill.

2.1 Model Setup

I consider two world regions: home and the rest of the world. The variables that refer to the rest of the world are identified by a superscript asterisk (*). Skilled and unskilled workers are distributed over continuums whose lengths are are L_s and L_u, respectively. Home is a relatively skill-abundant country, which is formally stated as follows:

$$(1)\ \frac{L_s}{L_u} > \frac{L_s^*}{L_u^*}$$

The two final goods are a skill-intensive product denoted by Y_s and an unskill-intensive product denoted by Y_u. I focus on the case in which Home exports the skill-intensive good. This is the most empirically appealing case and the prediction of a two-good two-factor model from any textbook.

Home is a small country with a Hicks neutral technological advantage. As a small country, the home country does not affect either good prices or foreign wages, which I then take as exogenous. Therefore, domestic wages, which are the endogenous variables, are expressed in terms of goods prices and foreign wages in equilibrium. Appendix 2 shows that if the home country were a large country, domestic wages could be written in terms of factor endowments, technologies, and the measure of transportation costs that I introduce below.

I conceptualize the production process in terms of tasks, which are of two types: skilled tasks and unskilled tasks. I follow GRH and assume that tasks performed using a given labor-type require similar amounts of that labor. In particular, I assume that skilled tasks require a unit of skilled labor and that unskilled tasks require a unit of unskilled labor. The tasks are specific-factors: skilled tasks are only used to produce Y_s and unskilled tasks are only used to produce Y_u. I normalize the measure of both skilled tasks and unskilled tasks to 1 like GRH. Technologies are given by the Cobb-Douglas functions used in Acemoglu et *al.* (2007)[2] and thus summarized by the following expressions:

$$(2)\, Y_s = Ae^{\int_0^1 ln(z_{i,s})di} \qquad (3)\, Y_u = Ae^{\int_0^1 ln(z_{i,u})di}$$

$$(4)\, Y_s^* = e^{\int_0^1 ln(z_{i,s}^*)di} \qquad (5)\, Y_u^* = e^{\int_0^1 ln(z_{i,u}^*)di}$$

where i is an index of tasks, $z_{i,j}$ denotes the amount of task $i \, \epsilon \, [0,1]$ used in the production of good and $A > 1$ denotes the home country's Hicks-neutral technological parameter. Note that the j-skilled tasks enter symmetrically in the production functions. Therefore, output is maximized as labor is equally distributed across tasks. Note also that the outputs are defined only if every single task is used.

The goods market is perfectly competitive, and trade costs, which are of the Samuelson-Bergson iceberg type (1952)[28], apply to both goods. In particular, for one unit of a product to arrive in the other region, τ ($\tau > 1$) must be shipped.

2.2 Goods Trade Equilibrium

The goods trade equilibrium is characterized by wages sequences $\{w_{i,j}\}_{i \, \epsilon \, [0,1]}^{j \, \epsilon \, [s,u]}$ that fulfill two sets of requirements: clearing of the task-markets and the zero-profit conditions.

Let me begin with market clearing of the task-markets. The output-constrained demands for tasks result from cost-minimization. Given the technology presented in equations (2)-(4), firms minimize costs and derive the following demands:

$$(6)\, z_{i,j}^d = (\frac{e^{\int_0^1 ln(w_{i,j})di}}{Aw_{i,j}})Y_j \quad \veebar \; j \, \epsilon \, [s,u] \, ; \, \veebar \, i \, \epsilon \, [0,1]$$

$$(7)\, z_{i,j}^{d\,*} = (\frac{e^{\int_0^1 ln(w_{i,j}^*)di}}{w_{i,j}^*})Y_j^* \quad \veebar \; j \, \epsilon \, [s,u] \, ; \, \veebar \, i \, \epsilon \, [0,1]$$

where $z_{i,j}^d$ is the output-constrained demand for task i in sector j, and $w_{i,j}$ is the price of that task. Note that the output-constrained demands are symmetric across the j-skilled tasks, which results from the symmetry in the production function that I mentioned above. This symmetry gives no demand-driven reasons for prices to be different in equilibrium; only if the supply of tasks were different could their prices differ in equilibrium. Furthermore, note that the output-constrained demand for task i in sector j is zero only when its price $w_{i,j}$ goes to infinite. This property guarantees that every task is used in equilibrium.

Consider the supply of tasks. A worker is able to perform any of the tasks at her skill level. Of these tasks, every worker prefers to supply the task(s) with the highest wage. Therefore, as long as a task does not have the highest wage, no worker will want to supply the task. More formally, if i'_j indicates the j-skilled task with the strictly highest wage, the supply of any task $i_j \,\epsilon\, [0,1]$ $i_j \neq i'_j$ will be equal to zero.

Using the output-contrained demands and the supply of tasks, I next characterize the equilibrium. A wage sequence $\{w_{i,j}\}_{i\,\epsilon\,[0,1]}^{j\,\epsilon\,[s,u]}$ that clears the task-markets is such that all the j-intensive tasks have the same price. In other words, any sequence for which there is a j-skilled task(s) i'_j with a strictly higher wage is not at an equilibrium.[6] More formally, if a sequence of wages clears the task-markets, this sequence is characterized by the following equations:

$$(8)\, w_{i,s} = w_s \;\veebar\; i\,\epsilon\,[0,1] \qquad w_{i,u} = w_u \;\veebar\; i\,\epsilon\,[0,1]$$

$$(9)\, w^*_{i,s} = w^*_s \;\veebar\; i\,\epsilon\,[0,1] \qquad w^*_{i,u} = w^*_u \;\veebar\; i\,\epsilon\,[0,1]$$

Equations (8) and (9) show the price-conditions under which the task markets clear. Plugging these conditions in the demands displayed in (6) and (7), I obtain the quantity of each task produced in equilibrium. These quantities are written as follows:

$$(10)\, z_{i,s} = L_s \;\veebar\; i\,\epsilon\,[0,1] \quad z_{i,u} = L_u \;\veebar\; i\,\epsilon\,[0,1]$$

$$(11)\, z^*_{i,s} = L^*_s \veebar\; i\epsilon\,[0,1] \quad z^*_{i,u} = L^*_u \;\veebar\; i\,\epsilon\,[0,1]$$

Equations (10) and (11) state that both skilled and unskilled labor are evenly allocated across tasks. If the world were perpetually well-described by this first regime, these allocations would also be the Pareto efficient allocations because they maximize output. In particular, when labor is evenly allocated across tasks, output in each industry is given by the following expressions:

$$(12)\, Y^1_s = AL_s \quad (13)\, Y^1_u = AL_u$$

$$(14)\, Y^{1\,*}_s = L^*_s \quad (15)\, Y^{1\,*}_u = L^*_u$$

where Y^1_j is the equilibrium output of good j in the first regime. Note in equations (12)-(15) that the production of each good is determined by countries' technologies and labor endowments of the specific factor. Furthermore, the two world-regions produce both goods so that incomplete specialization takes place in equilibrium.

[6] Appendix 2 shows this result.

Equations (8)-(15) define market clearing in the task markets. These equations, along with the zero-profit conditions, yield domestic wages in equilibrium. I next approach the zero-profit conditions. Under incomplete specialization, profits are zero when the effective price of each good equals its unit cost of production. Moreover, because the production functions displayed above summarize CRS technologies, the unit cost of production equal the marginal costs. These marginal costs are summarized by the following expressions:

$$(16)\, MC_j = \frac{e^{\int_0^1 ln(w_{i,,j})di}}{A} \;\; \veebar\; j\,\epsilon\,[s,u]\,;\; \veebar\, i\,\epsilon\,[0,1]$$

$$(17)\, MC_j^* = e^{\int_0^1 ln(w_{i,j}^*)di} \;\; \veebar\; j\,\epsilon\,[s,u]\,;\; \veebar\, i\,\epsilon\,[0,1]$$

where MC_j denotes the unit cost of production in sector j. The expressions displayed in (16) and (17) are readily simplified by imposing clearing in the task markets. Let me impose the price conditions under which task markets clear in equations (16) and (17). I then obtain the following expressions:

$$(16')\, MC_j = \frac{w_j}{A} \;\; \veebar\; j\,\epsilon\,[s,u]\,;\; \veebar\, i\,\epsilon\,[0,1]$$

$$(17')\, MC_j^* = w_j^* \;\; \veebar\; j\,\epsilon\,[s,u]\,;\; \veebar\, i\,\epsilon\,[0,1]$$

The last step in setting the zero-profit conditions is to equalize the unit costs displayed above to the effective price of the goods in each world region. The zero-profit condition are the written as follows:

$$(18)\, p^T = \frac{w_s}{A} \quad (19)\, \tau = \frac{w_u}{A}$$

$$(20)\, p^T\tau = w_s^* \quad (21)\, 1 = w_u^*$$

where p^T denotes the equilibrium relative price of the skill-intensive good, τ is the iceberg cost measure and the number 1 denotes that the price of the unskill-intensive good has been chosen as the numeraire. Equations (18)-(21) state that the effective price of the unskill-intensive good will be greater in the home country than in the rest of the world. This result is due to the existence of transport costs and the fact that the home country is a net importer of the unskill-intensive good.

Let me now rearrange equations (18)-(21) to display the relative wages by skill group. I will use these relative wages to address the effects of the ICT revolution in the next section. Rearranging equations (18)-(21) yields:

$$(22)\ \frac{w_s}{w_s^*} = \frac{A}{\tau} \quad (23)\ \frac{w_u}{w_u^*} = A\tau$$

The Home-to-foreign relative wages increase with Home's technological advantage for both skilled and unskilled labor (with the Hicks neutral technological parameter). Furthermore, if this advantage is sufficiently large, firms will find it profitable to offshore tasks from the rest of the world. Notice also that transportation costs have a varying impact on relative wages across regions. This statement is more formally written as follows:

$$(23)\ \frac{w_s}{w_u} = \frac{1}{\tau^2}(\frac{w_s^*}{w_u^*}) < \frac{w_s^*}{w_u^*}$$

Equation (23) shows that the skilled relative wage is lower for the home country than it is for the rest of the world. Transport costs do not allow trade in goods to equalize relative wages: these relative wages reflect differences in factor proportions and the home country's comparative advantage in the skill-intensive good. This non relative wage equalization across countries is the driving force in this model; because the skilled relative wage is lower for the home country, the impact of service offshoring will be heterogeneous across skill groups.

There is empirical evidence suggesting that skilled relative wages are lower in more technologically advanced (productive) nations. Psacharopulos [25] is the most comprehensive survey regarding differences in schoooling returns for the period preceding the ICT revolution.[7]Employing different comparable measures of schooling returns, among which there are skilled relative wages, the author finds that these returns are lower for the developed countries. Acemoglu [1] takes Psacharopulos' sample and shows that the skill-abundant countries have lower skilled relative wages.

Furthermore, other factor proportion models have emphasized the link between non-relative wage equalization and asymmetric offshoring effects. Deardorff's paper [13] is one example of these models. The author sets a one-product model and shows that if firms offshore production activities, relative wages will not equalize across countries. Unlike Deardorff, I conceptualize production in terms of tasks and thus choose a finer level of dissagregation for my model. My argument for justifying non-relative wage equalization is simpler than Deardorff's argument but still relasitic and empirically founded. Furthermore, the emphasis on the implications of service offshoring is stronger in my model.

[7]Note that schooling returns are not always measured as skill premia. However, as noted by the author, Psacharopulos (2002) the difference between the two represents a minor problem. Furthermore, since data quality is an issue and there are not many studies on differences in relative wages across developing and developed countries, I here refer to Psacharopulos (2002), which is the most comprehensive survey on the topic.

3 Trade In Goods And Tasks

I represent the ICT revolution with a fall in the costs of offshoring tasks. This fall gives place to the second regime of the model, in which offshoring costs become sufficiently low that firms decide to import tasks. I solve for domestic wages in equilibrium and compare these wages to those found in the previous section. The comparison yields the wage responses to service offshoring, which I use, along with the retraining model, to obtain the employment results.

3.1 Model Setup

In the previous section, the firms' only choice was to decide the amount of each task to purchase. In this section, firms also decide on which tasks to offshore. I let offshoring costs differ across tasks and determine a cutoff traded task, which I call I. Like GRH, I order tasks in each continuum so that offshoring costs are non-decreasing and a task's offshoring costs are indexed by i. These costs are expressed in terms of foreign labor requirements: a firm that performs task i abroad requires $\beta t(i)$ units of foreign labor, where the β parameter denotes the GRH shift parameter .

I model the ICT revolution as a discrete decrease in the β parameter value, which reduces offshoring costs unevenly across tasks. Therefore, only some of the tasks will be offshored in equilibrium under the assumptions that I display below; task i will be offshored if and only if its offshoring costs are lower than those of the cutoff traded task. In other words, task i will be offshored if and only if $i < I$.

To rule out the uninteresting case in which all tasks are imported, I assume that $t(.)$ is monotonic and "sufficiently increasing." This function is assumed to be twice continuously differentiable, which simplifies the exposition. I make an additional assumption to ensure that at least some skilled tasks are offshored. This condition guarantees that the first regime relative wage for skilled workers is sufficiently large. In particular, I make the following assumption:

$$(24)\ \frac{A}{\tau} > \beta t(0)$$

Assumption (24) has a straightforward interpretation: the technological advantage of the home country must be sufficiently large. When this advantage is sufficiently large, the first regime skilled wage is sufficiently great that domestic firms find it profitable to offshore skilled labor.

3.2 Goods and Tasks Trade Equilibrium

As in the previous section, the equilibrium is characterized by wage sequences $\{w_{i,j}\}_{i\,\epsilon\,[0,1]}^{j\,\epsilon\,[s,u]}$ that clear the task markets and fulfill the zero-profit conditions. However, because firms must decide on which tasks to offshore, an equilibrium sequence must fulfill an additional condition in this section: the task prices implied by the sequence must be such that the cutoff traded tasks are cost minimizing.

Let me first consider the cost minimizing condition. For this purpose, I determine a different cutoff for each skill group. There is a cutoff I_s that divides the continuum of skilled tasks into offshored tasks and non-offshored tasks. There is also a cutoff I_u that divides the continuum of unskilled tasks into offshored tasks and non-offshored tasks. Consider two observations regarding these cutoffs.

First, I allow the cutoffs to differ across skill groups and show that the equilibrium cutoffs are different in the next section. Second, the cutoffs do not distinguish between domestically-produced tasks and foreign-produced tasks. Because of the putty-clay assumption, all tasks are domestically-produced so that the cutoff tasks distinguish between imported and non-imported tasks. Kambourov and Manovskii (2009)[21] provide empirical support for the putty-clay assumption. The authors find evidence for the specificity of human capital and relate this specificity to the wage changes of the 1969-1997 period in a different paper (Kambourov and Manovskii[20]). Ritter (2008)[27] takes Kambourov and Manovskii's sample and finds that human capital is more specific in potentially tradable tasks.

Let me now return to the cost-minimizing choice of the cutoff traded tasks. Using equation (16), the firms' choices of the cutoffs are summarized by the following equations:

$$(25)\, Min_{J_s}\ MC_s(J_s) = \frac{e^{[1-J_s]ln(w_{nt,s})+\int_0^{J_s} ln(w_s^{*}\beta t(i))di}}{A}$$

$$(26)\, Min_{J_u}\ MC_u(J_u) = \frac{e^{[1-J_u]ln(w_{nt,u})+\int_0^{J_u} ln(w_u^{*}\beta t(i))di}}{A}$$

where J_j denotes a choice of the j's skill group cutoff, $w_j^{*}\beta t(i)$ is i task's effective importing price, and $w_{nt,j}$ is the price of any non-traded task. Notice in (25) and (26) that I impose the same price to all non-offshored tasks with the same skill intensity. Furthermore, I set the wage of each offshored task to its effective importing price. As I show below, wages must fulfill these conditions so that the markets of tasks clear in equilibrium.

The minimization problems presented in (25) and (26) yield straight-forward offshoring rules. These rules are displayed in the following equations:

$$-import\ task\ i\ if\ and\ only\ if\ \ w_s^*\beta t(i) < w_{nt,s}$$

$$-import\ task\ i\ if\ and\ only\ if\ \ w_u^*\beta t(i) < w_{nt,u}$$

Domestic firms offshore a task i if and only if importing this task reduces the marginal cost. Importing task i reduces the marginal cost if the importing price of the task is lower than its price in the domestic market $w_{nt,j}$. Based on the offshoring rules displayed above, I obtain equilibrium conditions for the cutoffs:

$$(27)\, w_{nt,s} = w_s^*\beta t(I_s) \quad w_{nt,u} = w_u^*\beta t(I_u)$$

where I_s and I_u are the skilled and the unskilled labor cutoffs in equilibrium, respectively. Equation (27) is a relationship between the price of the non-offshored tasks and the cutoff traded tasks. This Equation states that firms must be indifferent between offshoring and purchasing the equilibrium cutoff task in the domestic market. This equilibrium relationship, along with the zero-profit conditions that I address below, will determine the cutoffs traded tasks and the price for the non-offshored tasks.

Let me now turn to the second equilibrium condition: clearing in the domestic markets of tasks. The equilibrium employment level for an offshored task i_j''s is given by its inelastic supply and is equal to L_j like in the first regime. The equilibrium wage of the task is given by its effective importing price. For wages greater than $w_j^*\beta t(i_j')$, the demand for the task equals zero, so there is an excess supply. For wages lower than $w_j^*\beta t(i_j')$, the demand for the task is greater than the first regime demand and thus there is an excess demand.[8]This reasoning remains valid for any offshored task, independent of its offshoring costs. Therefore, the equilibrium wages of any imported task equal its effective import price, which confirms that the assumptions made in our discussion of the optimal offshoring rules are correct.

I address now equilibrium in the domestic market of a non-offshored task i_j''. Its employment level in equilibrium is given by the inelastic supply, as with offshored tasks. However, i_j'''s equilibrium wage must be lower than its import price; otherwise, firms may prefer to import the task. In particular, the equilibrium wage is given by the first regime demands for the tasks.[9]Therefore, i_j'' 's equilibrium wage is independent of its offshoring costs. This reasoning remains valid for any non-offshored task so that the equilibrium wage of any of these tasks is independent of offshoring costs. Furthermore, due to the symmetry in the production function, the equilibrium wage is the same for all non-offshored tasks. This finding confirms that the assumptions made in our discussion of the optimal offshoring rules are correct.

[8]Note that $w_j^*\beta t(i_j')$ is lower than the first regime's price of the task. Therefore, for wages lower than $w_j^*\beta t(i_j')$, the demand for the task is greater than the first regime demand, which implies an excess demand. Hence, the equilibrium wage is given by its importing price

[9]As I show below, the demands for the tasks muts be evaluated at the output level of the second regime.

Finally, let me address the last equilibrium requirement: the zero-profit conditions. These conditions yield the second relationship between the price of the non-offshored tasks and the cutoff traded tasks in equilibrium. As in the previous section, firms make zero-profits when unit production costs equal the effective prices of the goods. For unit costs, I use equations (25) and (26). For domestic prices, I use the small-country assumption. Because the home country is a small country and does not affect either good prices or foreign wages, equations (20) and (21) are still valid in this second regime. Setting the zero-profit condition yields

$$(30)\,\frac{w_s^*}{\tau} = \frac{e^{[1-J_s]ln(w_{nt,s})+\int_0^{J_s} ln(w_s^*\beta t(i))di}}{A}$$

$$(31)\,\tau w_u^* = \frac{e^{[1-J_u]ln(w_{nt,u})+\int_0^{J_u} ln(w_u^*\beta t(i))di}}{A}$$

Equations (30) and (31) implicitly define all vectors $(J_j, w_{nt,j})$ that fulfill the zero-profit conditions. Let me manipulate these equations to solve for the price of the non-offshored task. Manipulating equations (30) and (31), I obtain the following:

$$(30')\, w_{nt,s}(J_s) = e^{[ln(w_s^*)+\frac{ln(\frac{A}{\tau})-J_s ln(\beta)-\int_0^{J_s} ln(t(i))di}{1-J_s}]}$$

$$(31')\, w_{nt,u}(J_u) = e^{[ln(w_u^*)+\frac{ln(A\tau)-J_u ln(\beta)-\int_0^{J_u} ln(t(i))di}{1-J_u}]}$$

Equation (30') states that the price of a non-offshored skilled task depends on the home country's technological advantage, the transport cost measure, the GRH shift parameter, and the choice of the cutoff task J_s. Equation (31') is the corresponding equation for the price of unskilled tasks.

Note in (30') that the price of the non-offshored tasks decreases with any parameter change that reduces the unit production cost, holding the cutoff constant. Without loss of generality, consider a decrease in the unit production cost caused by a rise in the home country's Hicks parameter. As the home country becomes more productive, the price of the non-offshored tasks must rise so that the marginal cost returns to its original value. Only when the marginal cost returns to its original value, the zero-profit condition is restored.

Equation (30') returns the price of the non-offshored tasks that fulfills the zero-profits conditions for any cutoff choice J_s. I refer to this price as the "zero-profit wage" throughout the rest of the paper. Note in (30') that the zero-profit wage collapses to its first regime value when the cutoff choice equals zero. Specifically, the zero-profit wage collapses to the skilled wage implied by equations (18) and (20).

3.3 Offshoring And Wage Implications

I solve for the prices of the non-offshored tasks and the equilibrium cutoffs. For this purpose, I use the two equilibrium relationships between the endogenous variables: the optimal offshoring rules derived in (27) and the zero-profits conditions displayed in equations (30') and (31'). To obtain the wage schedule for the domestic economy, I will plug the equilibrium values of these endogenous variables into equations (28) and (29), the task-market clearing conditions. Next, I will run comparative statics that yield empirically testable cross-sectional predictions for countries with a different TFP level and a different trade costs parmeter.

3.3.1 Offshoring Implications And Empirically Testable Predictions

Figure 1 depicts the equilibrium for the particular case of a strictly convex offshoring cost function.[10]The solid and slightly weighted convex curve represents this function for the first regime. The vertical intercept of the curve is $\beta_0 t(0)$, which denotes the offshoring costs of the task that is cheapest to offshore. As the ICT revolution hits the economy, β goes from β_0 to β_1 $(\beta_1 < \beta_0)$, and the offshoring cost curve shifts downward. The new convex curve is more heavily weighted and represents the second regime. In the following, I refer to this curve as "the offshoring costs curve."

In Figure 1 the square-dotted curve depicts equation (31') when iceberg costs are given by τ^0. This curve shows the relationship between the zero-profit-to-foreign wage ratio $\frac{w_{nt,u}(J_u)}{w_u^*}$ and the cutoff choice J_u. The vertical intercept of the curve is the Home-to-Foreign unskilled relative wage of the first regime. The circle-dotted curve shows the corresponding relationship for skilled labor, derived by equation (30').

The equilibrium is given by market clearing in the task markets and the fulfillment of the zero-profits conditions and the optimal offshoring rules. For unskilled labor, this equilibrium lies at the intersection of the square-dotted and the offshoring cost curves $-J_u = I_u^{\tau^0}-$, as I show in Appendix 4. Equivalently, the equilibrium for skilled labor is given by the intersection of the circle-dotted and the offshoring cost curves. Note that the cutoff traded task is greater for unskilled labor than it for skilled labor $-I_u^{\tau^0} > I_s^{\tau^0}-$; therefore, the home country offshores more unskilled tasks than skilled tasks. Hence, this model claims that skill intensity is relevant to defining the propensity of a task to be offshored.

Note in Figure 1 that the cutoff traded tasks differ because the vertical intercepts of the square- and the circle-dotted curves are different.[11]In other words, the cutoff traded tasks differ because the relative wages from the first regime do not equalize across countries (and therefore neither the vertical intercepts, which represent the Home-to-Foreign relative wages for the two skill groups). The logic behind this result is as follows: because the home country is skill-abundant, its unskilled relative wage from the

[10]We do not require this second derivative to be positive over the whole range of tasks; however, it gets easy to expose the economic effects triggered by service offshoring in this case.

[11]Appendix 4 proves this result.

first regime is greater than its skilled relative wage. Therefore, firms find it more profitable to offshore unskilled labor and import a relatively larger set of unskilled tasks. In other words, the home country's skill abundance explains why relative factor prices do not equalize and, ultimately, why the the cutoff traded tasks differ across skill groups. Hence, this model uses a factor proportion argument to generate asymmetry in the cutoff traded tasks. The model makes this argument without neglecting the role of tradability and thereby reconciles GRH's model with factor proportion setups.

Figure 1.
Cutoffs for the case of low trade costs.

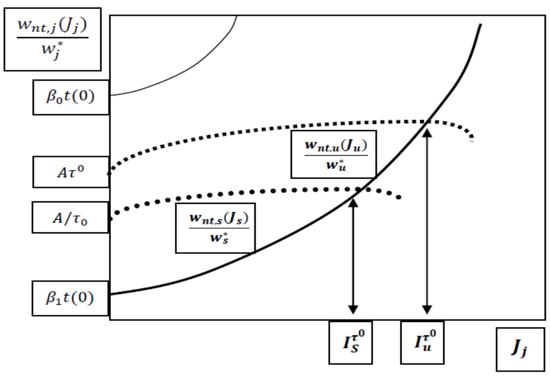


Figure 2.
Cutoffs for the case of high trade costs.

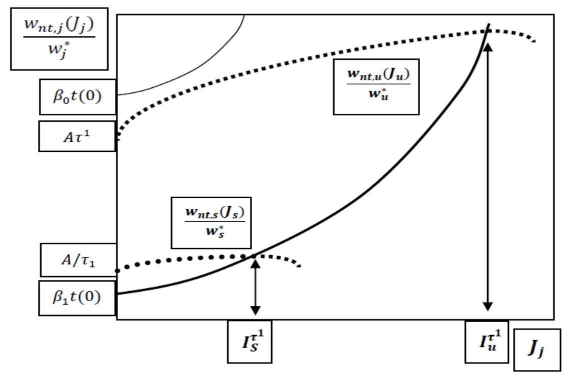


Figure 2 depicts the equilibrium for the case of a higher trade costs parameter, denoted with τ^1 ($\tau^1 > \tau^0$). Let me now compare Figures 1 and 2 with the goal of assesing the impact of a trade costs increase. As trade costs increase, the square-dotted curve shifts upward, and the circle-dotted line shifts downward. The trade costs increase then enlarges the set of unskilled offshored tasks and shrinks the set of skilled tasks.[12]The intuition for this result goes as follows: the trade costs increase exacerbates the impact of the home country's skill abundance on relative factor prices. Specifically, higher trade costs reduce the domestic relative wage for the skilled group and increase the domestic relative wage for the unskilled group. The trade costs increase then makes it more profitable to offshore unskilled labor and therefore the difference between the cutoff traded tasks increases. Hence, this model predicts that countries with higher trade costs will offshore more unskilled tasks and fewer skilled tasks.

The link between trade costs and relative wages was the highlight of other papers in the literature. For example, Redding and Schott (2003)[26] show that countries located further from global economic activity have a lower skill premium. The intuition for this result could be found via the Stolper–Samuelson theorem because increased remoteness has the same effect as a reduction in the relative price of the skill-intensive good.[13]This intuition is also behind the decrease in the first regime skilled relative wage for

[12]See Appendix 4 for a proof of this result.
[13]The author showed this result for the case in which manufactured goods were relatively skill intensive and face relatively large trade costs.

the home country in my model. However, I argue that a lower skilled relative wage has a second order effect for skilled workers due to service offshoring. In other words, remoteness benefits skilled workers regarding service offshoring effects.

Note that a rise in the β parameter moves the economy away from service offshoring and back to the first regime.[14]This model then predicts that countries with higher offshoring costs import smaller sets of both skilled and unskilled tasks. Consider now an increase in the Hicks parameter. Because a higher productivity in final goods increases domestic wages, service offshoring becomes more profitable and thus firms import larger sets of tasks. Hence, this model predicts that more productive countries will offshore more tasks. This prediction, like that referring to changes in the trade cost measure, is testable and can be confronted with applicable data.

3.3.2 Wage Impacts And Testable Implications

In order to draw intuition on the wage impacts of service offshoring, let me introduce the productivity and foreign competition effects. Offshoring allows firms to hire cheaper labor and thus reduces firms' costs, or equivalently, offshoring increases firms' productivity. The productivity increase expands output and therefore increases the demand for domestic labor. Consequently, the productivity effect tends to increase domestic wages.[15] [16]On ther hand, offshoring increases the exposure to foreign competition. Because firms can purchase an offshored task at its effective importing price, the equilibrium wage of this task cannot be greater than its import price. In other words, service offshoring prevents the wages of the offshored tasks from being greater. Let me call this negative offshoring effect on domestic wages the foreign competition effect.

The productivity and foreign competition effects determine the skilled losers and the skilled winners from service offshoring, depicted in Figure 3. In this figure, the square-dotted curves denote the wage schedule for skilled workers, and the horizontal line indicates their first regime wage. The intersection between these two curves, indicated by a point and a solid vertical line, can be used to identify the indifferent skilled task i_s^h. Workers fulfilling this task receive the same wage in the first and second regimes. Figure 4 displays the corresponding information for unskilled workers.

Let me distinguish between three regions in Figures 3 and 4. The first region is located further right and refers to the workers fulfilling non-traded tasks. Service offshoring increases the wage of these workers because of the productivity effect; not surprisingly, workers whose tasks are not offshored benefit from

[14]See Appendix 4 for the proof.

[15]The productivity effect can be seen in Figure 1. Consider the case of unskilled labor and low trade costs in this figure. Over the set of tasks located to the left of the equilibrium $-J_u < I_u^{\tau^0} -$ the zero-profit price of a non-offshored task is greater than its effective import price; thus, firms save money and reduce their marginal costs by offshoring these tasks.

[16]Heshmati (2003)[16], Olsen (2006)[24] and Amiti and Wei (2009)[4] are examples of papers that approach this effect from an empirical perspective.

service offshoring.

The second region refers to workers employed in offshored tasks whose offshoring costs are relatively low; they are located further to the left in Figures 3 and 4. Service offshoring harms these workers through the foreign competition effect. Notice that the foreign competition effect does not act homogeneously across tasks: the cheaper it is to offshore a worker's task, the more she suffers from service offshoring. This result is intuitive because, as I noted in the introduction, physicians and radiologists are not expected to be equally affected by service offshoring. This paper then illustrates the effect of foreign competition differently from GRH, in which foreign competition is isomorphich to a domestic labor supply increase and thus harms all workers to the same extent.

Figure 3.
Wage schedule for skilled workers.

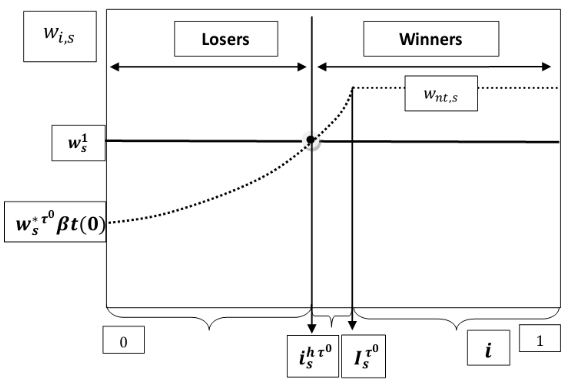
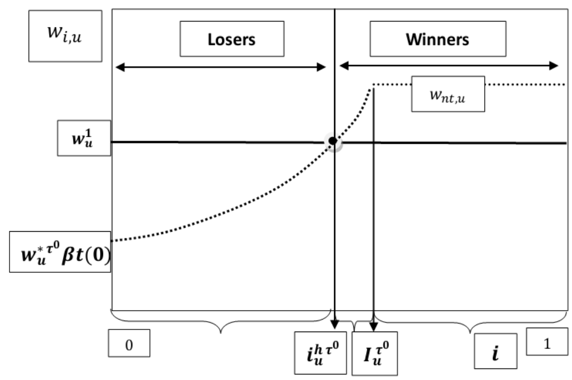


Figure 4.
Wage schedule for unskilled workers.



Let me consider the third region, which concerns workers employed in offshored tasks with relatively high offshoring costs. These workers are located to the left of the equilibrium cutoff traded tasks. Unexpectedly, these workers benefit from service offshoring even though tasks of their type are offshored. Workers employed in offshored tasks with relatively high offshoring costs benefit from the productivity effect more than they suffer from the foreign competition effect. Note the difference with respect to GRH, in which all workers with the same skill level either benefit or suffer from service offshoring. Workers from the third regions of Figures 3 and 4 are represented in Figure 5, which displays the market for an offshored task i'_j benefiting from offshoring, and the market for a non-offshored task.

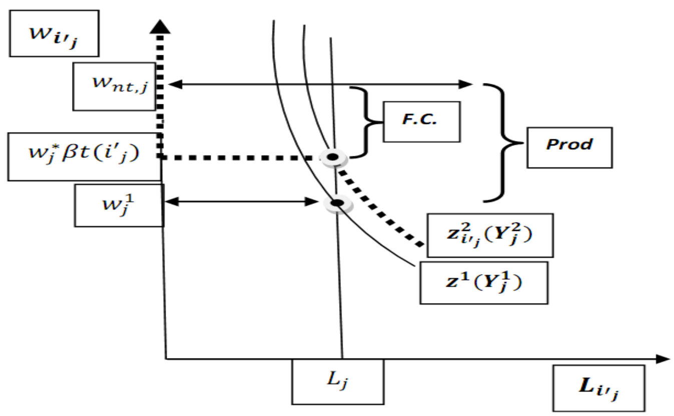
In Figure 5 the first regime equilibrium wage for both tasks $-w_j^1-$ lies at the intersection of the inelastic supply and demand, denoted by $z_1(Y_j^1)$ and indicated by a solid line. The second regime demand for the offshored task, denoted by $Z^2_{i'_j}(Y_j^2)$, is represented by square dotted curves. Note that the third chunk of this demand results from the shift in $z_1(Y_j^1)$ due to the production increase generated by the productivity effect $-Y_j^2 > Y_j^1$-.

The non-offshored task does not suffer from the foreign competition effect, then this effect is the difference between its wage and the wage of the offshored task. The difference between the first and the second regime wages for the non-offhored task (the vertical distance between w_j^1 and $w_{nt,j}$) yields the productivity effect (tagged as Prod). As shown in Figure 2, the productivity effect is stronger than the foreign competition effect, then the workers who are completing task i'_j gain from service offshoring.

Let me now return to Figures 3 and 4 to compare the wage schedules for unskilled and skilled workers. The proportion of "loser tasks" is greater for unskilled labor than it is for skilled labor.[17]Furthermore, Figures 3 and 4 yield the intuitive result that "unskilled losers" lose more than "skilled losers" in terms of wage ratios, given offshoring costs; given two workers with different skill-levels, the unskilled worker will have a lower second-to-first regime wage ratio. Hence, this model claims that the ICT revolution more strongly harms unskilled workers despite the fact that losers are not fully determined by skill-levels.

Figure 5.

Productivity and Foreign Competition effects.



Finally, let me investigate the effects of a trade cost increase on the sets of winners and losers from trade. As noted above, a trade cost increase reduces the first regime Home-to-foreign wage for skilled labor and increases this wage for unskilled labor. Figures 6 and 7 represent these changes with an increase in the foreign skilled wage and a decrease in the foreign unskilled wage. The trade cost increase reduces the ratio of non-offshored-to-foreign wage (and the non-offshoted-to-first-regime wage ratio) for skilled labor and increases this ratio for unskilled labor. These changes are depicted in Figures 6 and 7 with shifts of the wages for the non-offshored tasks.

Note in Figures 6 and 7 that the trade cost increase creates new "skilled winners" and new "unskilled losers." Higher trade costs emphasize the relative skill abundance of the home country. The trade cost increase reduces the first regime skilled relative wage, which makes foreign competition less intense for skilled workers but more intense for unskilled employees. Therefore, the trade cost increase reduces the number of losers among skilled workers but increases this amount among unskilled workers. Hence, the

[17] I show this result in Appendix 5.

model predicts that skilled workers from countries facing higher trade costs will be less likely to lose from service offshoring.

Let me now compare countries with different values for the GRH shift parameter. As noted above, an increase in this parameter moves the economy back to the first regime so that foreign competition becomes less intense for both skilled and unskilled workers. Therefore, countries that are more isolated in terms of service offshoring should have fewer losers, independent of the skill-level considered. On the other hand, if the GRH shift parameter goes to zero, all tasks in the economy will be offshored in the same amount. In this two-good infinite-input economy, the wage of every j-skilled task will equal the wage perceived by the j-skilled workers in the rest of the world. In other words, as the GRH parameter becomes zero, there is factor price equalization across regions. In terms of the theory of lenses developed by Deardorff [12], the factor price equalization (FPE) region becomes the entire factor space when beta equals zero.

Consider differences across countries with a different final goods productivity. An increase in the Hicks neutral raises the home country's wages of the first regime but intensifies competition for both skill groups. Therefore, a higher final goods productivity enlarges the set of losers for both unskilled and skilled labor. Hence, this model predicts that a worker from a skill-abundant country with a higher final goods productivity is more likely to lose from service offshoring. The key to this result is that technological advantage is not diminished by importing tasks.[18]

Figure 6.
Trade costs increase and skilled wages.

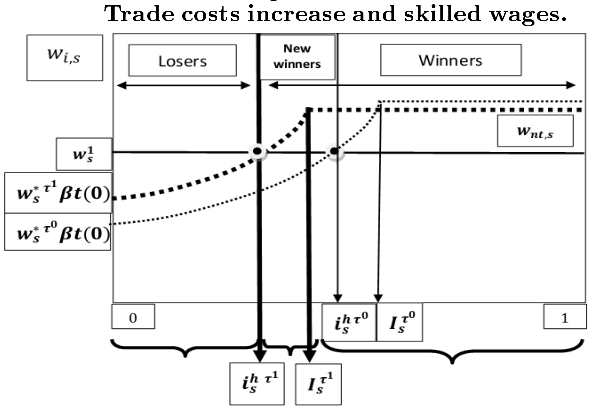
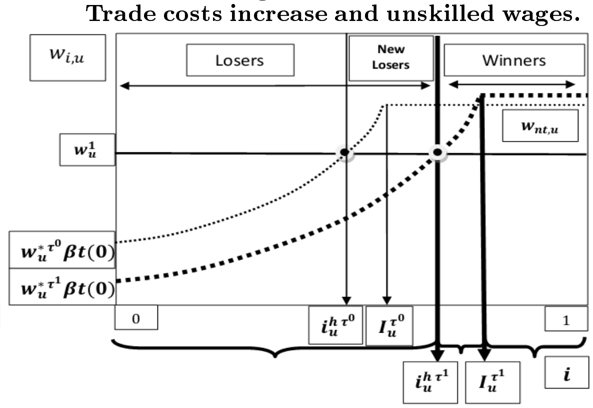


Figure 7.
Trade costs increase and unskilled wages.



In conclusion, the comparison between the first and second regimes shows that both skill intensity and tradability are relevant to the determination of whether a task is offshored. Furthermore, the two labor dimensions are relevant for assessment of losers from the ICT revolution.

[18] Appendix 4 provides proofs of these predictions and the prediction regarding changes in the trade cost measure.

4 The Retraining Process

I have showed that service offshoring creates wage differences across tasks that have the same skill intensity. Workers employed in low-paid tasks then have incentives for fulfilling a different task. Because knowledge is task-specific, these workers must undergo a retraining process that I model in this section. The retraining model yields the employment responses to service offshoring: employment will increase for the non-offshored tasks and it will decrease for the tasks in which at least one worker retrains.

Workers make two retraining decisions. First, they decide whether to invest in retraining or maintain their current task. On the one hand, retraining allows workers to get a non-traded job and benefit from a wage increase. On the other hand, retraining entails costs and thus it forces retrainees to give up part of their incomes. Second, retrainees make decisions regarding their retraining plans. They decide the duration of their retraining programs, R, and the number of retraining hours per period, h^t.

Worker heterogeneity will generate different retraining decisions. A worker's retraining decisions will depend on her pre-ICT revolution task, which will determine the value of retraining for her: the higher the difference between the worker's wage and the wage of a non-offshored task, the more willing she will be to retrain. Therefore, only workers whose tasks have sufficiently low wages will make the human capital investment.

Furthermore, workers within the same pre-ICT revolution task may differ in their ability to retrain. I assume that the retraining productivities of the L_j workers fulfilling j-skilled task i are distributed according to a c.d.f. $g_{ij}(.)$ with support $(\underline{a}_{ij}, \bar{a}_{ij})$, where $g_{ij}(a^h)$ indicates the proportion of workers whose productivity is lower than a^h. I assume that individuals are identically distributed across tasks; then $\underline{a}_{ij} = \underline{a}$; $\bar{a}_{ij} = \bar{a}$ *and* $g_{ij}(.) = g(.)$ $\veebar j \,\epsilon (s,u) \veebar i \,\epsilon (0,1)$ *and* $\veebar$ $a^h \,\epsilon (\underline{a}, \bar{a})$. The assumption of equal distributions across tasks is consistent with the characteristics of my setup: perfect competition in which labor returns equal the marginal productivity of labor and agents do not expect the ICT shock.

Without loss of generality, I assume that workers' work lives equal T periods. Furthermore, to simplify the decision-making process, I follow Ben-Porath's (1967)[6] seminal paper on human capital investment. In particular, I make the same assumptions as Ben-Porath, which are as follows:

1. Individual utility is not a function of activities involving time as an input.
2. An amount of time per period, normalized to 1, is allocated to activities producing earnings and retraining.
3. Complete asset markets: borrowing and lending takes place at a constant rate r.

Under these assumptions, workers base their retraining decisions on their lifetime income. Therefore, 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. I will not address the retraining-non retraining decision for now and will instead analyze workers' optimal retraining programs. The decision to retrain will follow from this analysis: workers making long-term plans will prefer to avoid retraining and maintain their task.

When designing their programs, workers choose the sequence $\{h^t\}_{t=0}^{R}$ and duration R that maximize their lifetime income under the retraining option. In particular, a worker completing the j-skilled task i whose retraining productivity is a_h maximizes the following expression:

$$(32)\, Max_{\left\{h_{i,j}^{a^h}{}^t\right\}_{t=0}^{R_{i,j}^{a^h}};\, R_{i,j}^{a^h}} I_{i,j}^{a^h,Ret} = \int_0^{R_{i,j}^{a^h}} (1 - h_{i,j}^{a^h}{}^t)[w_j^* \beta t(i)] e^{-rt} dt + \int_{R_{i,j}^{a^h}}^{T} w_{nt,j} e^{-rt} dt$$

where $I_{i,j}^{a^h,Ret}$ is the worker's lifetime income under the retraining option, $h_{i,j}^{a^h}{}^t$ is her amount of retraining hours in period t and $R_{i,j}^{a^h}$ is the amount of periods the worker chooses for her retraining plan. Equation (32) shows the trade-off faced by the retrainee when allocating the fixed amount of time per period. As the worker allocates more of her time to retraining, she accelerates the retraining process. However, she must then spend fewer hours at work$-(1 - h_{i,j}^{a^h}{}^t)-$, which reduces her labor income for that period.

I conceptualize the retraining process with a C.E.S. learning production function, which allows me to represent two features of the learning process. First, the C.E.S. technology illustrates that knowledge is better assimilated when spread over time, so that "crammers" must spend more hours to obtain the same retraining results. Second, this technology illustrates that retrainees become tired after a long learning session and therefore are less productive at retraining in a given period. Retrainees complete their learning process as they "produce" θ effective retraining hours. Therefore, the worker mentioned above maximizes equation (33) subject to the following constraint:

$$(33)\, \theta = Q_{i,j} = a_h \left[\int_0^{R_{i,j}^{a^h}} (h_{i,j}^{a^h}{}^t)^\rho dt \right]^{\frac{1}{\rho}}$$

where $Q_{i,j}$ indicates the worker's number of effective hours and $\rho < 1$ is a parameter of the production function, which measures the sensitivity of the learning process to the length of the retraining program. The efficiency of the learning process increases with the duration of the retraining program, which represents the "cramming assumption." The marginal productivity of hours is decreasing for a given period t, which represents that students become tired after a long session.

When building her plan, the worker faces a time-constraint limiting the retraining duration: no retraining program can last more than T periods, the length of any worker's lifetime. I abstract from this constraint when solving the optimization problem, but I impose it to the unconstrained solution displayed below. Given these considerations, the optimal sequence $\left\{h_{i,j}^{a^h}{}^t\right\}_{t=0}^{R_{i,j}^{a^h}}$ is characterized by the following first order conditions:

$$(34)\; \lambda_{i,j}^{a^h\,*} = \frac{w_j^* \beta t(i)}{a_h}[(\frac{1-\rho}{r\rho})(e^{R_{i,j}^{a^h}(\frac{r\rho}{1-\rho})}-1)]^{-(\frac{1-\rho}{\rho})}$$

$$(35)\; h_{i,j}^{a^h\,t^*} = \frac{\theta}{a_h}[(\frac{1-\rho}{r\rho})(e^{R_{i,j}^{a^h}(\frac{r\rho}{1-\rho})}-1)]^{-\frac{1}{\rho}} e^{\frac{rt}{1-\rho}}$$

Equation (34) displays the cost of the marginal effective retraining hour $\lambda_{i,j}^{a^h\,*}$. Due to the "cramming assumption" this cost decreases as the length of the retraining process increases. The logic of this argument is as follows: the longer the plan duration, the fewer the total amount of hours the worker spends on retraining. Equation (35) displays the optimal duration in terms of the number of hours for a given period t. To find this duration in equilibrium, let me plug equation (35) into the lifetime income definition displayed in (32). I then obtain an expression that depends only on $R_{i,j}^{a^h}$. Maximizing this expression yields the following choice:

$$(36)\; e^{-rR_{i,j}^{a^h}}[w_{nt,j} - w_j^* \beta t(i)] = \frac{\theta w_j^* \beta t(i)}{a_h} r^{\frac{1}{\rho}} [\frac{1-\rho}{\rho}]^{-[\frac{1-\rho}{\rho}]} e^{R_{i,j}^{a^h}[\frac{r\rho}{1-\rho}]} [e^{R_{i,j}^{a^h}[\frac{r\rho}{1-\rho}]} - 1]^{-\frac{1}{\rho}}$$

Equation (36) illustrates the trade-off faced by a retrainee when choosing the duration of her plan. The LHS of the equation shows the disadvantages of a long retraining process. When the plan duration increases by one period, the worker begins her new higher income task one period later. She then benefits from a higher wage during one fewer period. The RHS of the equation shows the advantage of a long retraining plan. As the duration increases by one period, the marginal cost of effective retraining falls and thus the worker gives up less income.

There are workers who design such long retraining plans that their lengths cannot be found using equation (36). For these workers, the marginal benefit from increasing the plan is greater than the marginal cost at any $R_{i,j}^{a^h} \epsilon R$. Therefore, if these workers lived an infinite number of years, they would design perpetual retraining programs. Because perpetual programs are not feasible, I force these workers to design T-period retraining plans. As shown in Appendix 6, this strategy is optimally conditional on choosing the retraining option. More formally, I impose the following condition:

$$(37) \qquad R_{i,j}^{a^h\,*} = T \qquad if: \frac{w_{nt,j}}{w_j^* \beta t(i)} < 1 + \frac{\theta}{a^h} r^{\frac{1}{\rho}} [\frac{1-\rho}{\rho}]^{-[\frac{1-\rho}{\rho}]}$$

Equation (37) defines the set of workers whose plan length does not solve equation (36). As noted above, I set these lengths to T. Notice in equation (37) that the inequality becomes less restrictive as the i index rises. Therefore, employees in this set tend to work in offshored tasks with high offshoring costs. In addition, the inequality becomes less restrictive as the zero-profit-to-foreign wage ratio falls. Because this ratio is lower for the skilled workers, the proportion of tasks in the set is greater for skilled labor.[19] For now, let me exclude the set defined in (37) and concentrate on the rest of the workers. These workers' plan lengths are obtained from equation (36) and are written as follows:

$$(38)\ if:\ -[\frac{1-\rho}{r\rho}]Ln[1-\frac{r[\frac{\rho}{1-\rho}]^{1-\rho}}{[\frac{\bar{a}}{\theta}[\frac{w_{nt,j}}{w_j^*\beta t(i)}-1]]^{\rho}}]=B_{i,j}^{a^h}\leq T \qquad R_{i,j}^{a^h\,*}=B_{i,j}^{a^h}$$

$$Otherwise \qquad R_{i,j}^{a^h\,*}=T$$

Statement (38) is composed of two lines. The first line corresponds to workers whose retraining programs are shorter than their lifetime. The lengths of these workers' programs depend on their retraining productivity and their pre-ICT revolution task. More specifically, more productive workers design short retraining plans. Furthermore, unskilled workers and employees in tasks with low offshoring costs finish their retraining processes more rapidly. The reason is that these workers benefit from a higher wage increase in switching to non-offshored. Therefore their marginal loss for designing a long retraining plan is greater and they prefer to finish retraining earlier.

The second line in statement (38) corresponds to workers whose retraining plans are longer than their lifetimes. Here, there is a higher proportion of skilled tasks, and employees tend to work in tasks with high offshoring costs. The lengths of these workers' retraining programs are not feasible, even though they can be found using equation (36). Consequently, I impose these programs to last T periods, which, as shown in Appendix 5, is these workers' best strategy conditional upon their choosing the retraining option.

Let me now turn to the retraining-non-retraining decision. As noted above, workers retrain if and only if their lifetime income is greater under the retraining option than it is under the non-retraining option. A worker's lifetime income under retraining is defined by equations (37)-(38), which I use to calculate the income difference for the two options. For the worker mentioned above, this difference is as follows:

$$(39)\ I_{i,j}^{a^h,Ret}-I_{i,j}^{a^h,NoRet}=[\frac{w_{nt,j}-w_j^*\beta t(i)}{r}][e^{-R_{i,j}^{a^h\,*}[\frac{r}{1-\rho}]}-e^{-rT}]$$

where $I_{i,j}^{a^h,NoRet}$ is the worker's lifetime income under the non-retraining option. From equation (39), we know that this worker will retrain *if and only if*:

[19] Because $\frac{w_{nt,s}}{w_s^*}<\frac{w_{nt,u}}{w_u^*}$, as shown in the previous section.

$$(40)\ R_{i,j}^{a^h *} < T[1-\rho]$$

A worker will retrain only if the duration of her optimal retraining plan conditional on retraining is sufficiently small. Therefore, retrainees tend to work in tasks with low offshoring costs. For these workers, retraining is profitable because their "after-retraining lifetime" is sufficiently long for them to recover their human capital investment. Moreover, notice that workers whose programs are forced to last T periods and who are employed in tasks with high offshoring costs choose not to retrain.

Furthermore, equation (40) states that the proportion of tasks in which at least one worker retrains is higher for unskilled tasks. To explain this result, I will derive the condition under which there is retraining in an task. There is retraining in the j-skilled task i if at least the most productive workers make the human capital investment. More formally, this statement is written as follows:

$$(41)\ R_{i,j}^{\bar{a}*} \leq T[1-\rho]$$

If equation (41) is not fulfilled, there is no retraining in this task. Furthermore, because the length of a retraining plan increases smoothly with the offshoring cost of tasks, equation (41) implicitly defines the j-cutoffs under which there is retraining. I refer to these cutoffs as "retraining cutoffs", which can be found using the following expression:

$$(42)\ R_{\bar{I}_j}^{\bar{a}*} = T[1-\rho]$$

where $\bar{I}_j$ is the j-skilled retraining cutoff task. As shown in Appendix 6, the retraining cutoffs increase with the zero-profit-to-foreign wage ratio. The logic is as follows: an increase in the zero-profit-to-foreign wage ratio makes retraining more profitable, so workers retrain in a larger proportion of tasks. Furthermore, because the zero-profit to foreign wage ratio is greater for unskilled workers, the set of tasks in which at least one worker retrains is greater for unskilled labor.

5 Predictions Of The Model And Empirical Evidence

I use the retraining cutoff tasks derived in the last section to study the employment predictions of the model. I show how these predictions relate to the empirical evidence presented in the introduction and to the wage results derived in section 3. The relationship between the employment and the wage results is consistent with recent empirical findings.

Figure 8 summarizes the predictions of the model. As noted in previous sections, service offshoring creates a labor reallocation. The tasks in which employment increases because of the labor reallocation are determined by the cutoff traded tasks. In Figure 8, these tasks are indicated by the square dotted lines located further right on the continuums labeled “Employment.” Figure 8 shows that employment decreases in the more offshorable tasks, which is consistent with the arguments made by the authors that emphasize the tradability dimension of labor. Note that the set of tasks with a positive employment response is larger for the skilled tasks, which is represented in Figure 8 by a larger square dotted line on the upper continuum. In other words, this paper predicts that the two labor dimensions are relevant for understanding the employment effects of service offshoring. This result is consistent with the empirical evidence provided by Crino. My model predicts that employment responses are more likely to be positive in skilled occupations, given offshorability.[20]Furthermore, the model predicts that employment responses are more likely to be positive in less offshorable tasks, given skill intensity. These are the empirical findings provided by Crino.

The set of tasks in which employment falls due to service offshoring is determined by the retraining cutoff tasks. In Figure 8 these tasks are indicated by solid lines with different weights. The proportion of tasks losing employment is greater for the unskilled tasks because the retraining cutoff is greater for unskilled labor. This result matches the evidence presented by Crino because the negative employment responses are concentrated among the unskilled tasks. Note also that for some tasks there are not any lines in Figure 8. These tasks are those for which the retraining gains are not sufficiently large and therefore the tasks for which no worker retrains. Because no worker retrains in these tasks, their employment level remains the same.

In addition, the paper makes predictions about the magnitude of the employment changes. The magnitude of the employment changes are expressed in rates of change and indicated by different weights in Figure 8. As we move left on the continuums, the lines become heavier weighted: easily offshorable tasks have higher rates of employment losses. The proof for this result is given by equation (40). Note in this equation that the proportion of workers fulfilling the inequality decreases with the offshoring costs of the tasks. Furthermore, this proportion is greater for unskilled labor, given two tasks with the same offshoring costs. Hence, this model predicts that the rates of employment losses are greater for unskilled tasks, given offshoring costs. These predictions are empirically testable and then open an avenue for further empirical research.

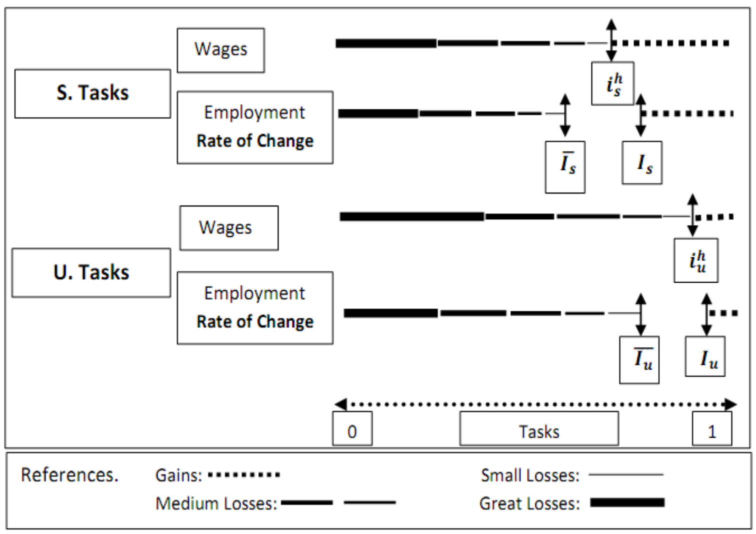
Let me make a final comment on the employment predictions. As noted in the last section, the model bases these predictions on different retraining lengths across heterogeneous workers. In this regard, it is important to note that the different lengths of retraining yield a gradual adjustment to new employment levels. Furthermore, a gradual adjustment toward the new employment levels is intuitive and seems fairly realistic.

[20]This statement requires a mapping between tasks and occupations. Because the statement refers to occupations with the same tradability, any mapping would confirm the result.

Figure 8 depicts the wage predictions of the model, as well. This Figure shows that the unskilled tasks are more likely to have losers. In addition, Figure 8 replicates the results displayed in section 3: unskilled losers lose more than skilled losers, given offshorability. However, losers and winners are not fully determined by skill group: employees suffering from wage losses work in the low-offshoring costs tasks. The model is consistent with Hummels et *al.*'s evidence because it argues that both tradability and skill intensity determine an occupation's wage response. Because the model generates positive correlation between wages and employment changes it matches the empirical evidence provided by Crino.

Figure 8.

Summary of results for low trade costs.



Consider now the cross-sectional predictions for countries with different characteristics derived in Section 3. As shown in Section 3, countries with high trade costs offshore a larger set of unskilled tasks and a smaller set of skilled tasks. Therefore, the model predicts that countries facing higher trade costs have a smaller (larger) set of skilled (unskilled) tasks in which employment increases. Moreover, a trade costs increase reduces the zero-profit-to-foreign wage ratio for skilled labor and raises this ratio for unskilled labor. The retraining cutoffs are increasing in these ratios, then this model predicts that countries with higher trade costs in goods have a smaller set of skilled tasks and a larger set of unskilled tasks losing employment. Finally, countries that have a higher GR-H parameter are closer to the first regime's situation and more advanced technological nations are closer to the second regime.

6 Concluding Remarks And Lines For Further Research

International competition used to occur between firms from different countries and sectors of different skill intensity.Trade liberalization then created winners and losers from trade by skill-level so that theory and empirics focused on the skill dimension of labor. Standard trade theory emphasized the Stolper-Samuelson theorem, and the empirical literature related trade to skill-premium behavior.

The ICT revolution has reduced communication and coordination costs changing the nature of international competition. International competition seems to be occurring now at a much finer level of disaggregation, causing job characteristics other than skill intensity to have important roles. We would expect tradability to have an important role because labor tasks are of varying natures; tasks differ in their degrees of complexity, their requirements of personal interaction, their levels of routines, and the difficulties of their instructions to be understood by foreign workers.Therefore, we would expect the ICT revolution to have a varying impact on offshoring costs and thus on the wages and on the employment of these tasks.The novelty in this paper (and the main difference with respect to GRH) is that tradeability plays a central role in the determination of wages and employment responses. Tradeability seems intuitively relevant and has been highlighted by several authors.[21]

This paper shows that the effect of service offshoring depends on tradability and thus varies within skill groups. More offshorable tasks are easier to substitute with foreign labor and thus their wages and employment are more likely to fall due to service offshoring. Therefore, more offshorable tasks are more likley to be harmed by service offshoring. On other hand, service offshoring benefits domestic workers because its impact is isomorphic to an increase in the productivity of domestic firms. Because domestic firms hire cheaper labor, their production expands and their demand for domestic labor increases. Consequently, even though offshoring harms more offshorable tasks, not every offshored task loses from service offshoring. Although the paper emphasizes tradability, its findings are consistent with the standard trade theory because it yields employment and wage responses that also depend on skill intensity. Skilled workers are more likely to benefit and unskilled workers are more likely to lose due to service offshoring.

Furthermore, the paper provides the empirical work with a guide for further research. Although several authors have emphasized tradability, there are still few paper to check if tradability predicts offshoring. The model I develop proposes further investigation on the characteristics of a task that determine its propensity to be offshored. The cross-sectional predictions for countries with different characteristics proposed in this paper provide additional lines for further empirical work. Later empirical research could address these predictions using applicable data. Testing these predictions requires datasets with fine levels of disaggregation not available in the past; however, more labor market data

[21] Van Welsum and Vickery [31], Baldwin [5], Blinder [8], Jensen and Kletzer [18], and Crino [10] are examples of empirical studies that highlight the importance of tradability.

have recently become available for developed countries. On the other hand, data availability represents a major constraint hampering investigations of the effects of the ICT revolution on developing countries. Apropos of developing countries, it would be particularly interesting to investigate if their wage behavior follows the logic proposed in this paper. Following the logic of this paper, the ICT revolution might have increased service exports and thus the wages of more offshorable tasks in countries like India or China. Therefore, the ICT revolution might have given these countries a great opportunity for developing their economies. Ultimately, this is empirical question, which will hopefully have an answer when data becomes more available.

This paper also opens up a line of research linking expectations of the ICT revolution and ex-ante outcomes. This link has not been explored and is of great importance given that the ICT revolution occurred in the 1990s. This decade was a period of frequent economic change and rapid information flow, in which workers most likely formed expectations on the shock. Thus, it would be interesting to study how a decentralized mechanism can generate different ex-ante outcomes in a framework augmented with expectations. Finally, the paper encourages research of the role of public policy in the context of an ICT revolution. Many questions remain to be answered regarding this role. I give a first step in this direction in Appendix 1, in which I show that a well-infromed government that anticipates the shock is able to generate a Pareto improving allocation across tasks. However, my Appendix does not consider assymetric information between the government and the workers, which is a realistic aspect to be considered. An interesting avenue for further research then concerns the implications of asymmetric information between policy makers and other economic agents.

References

[1] D. Acemoglu. Patterns of skill premia. *The Review of Economic Studies*, 70(2):199, 2003.

[2] D. Acemoglu, P. Antràs, and E. Helpman. Contracts and technology adoption. *The American economic review*, pages 916–943, 2007.

[3] M. Amiti and S.J. Wei. Fear of service outsourcing: is it justified? *Economic Policy*, 20(42):308–347, 2005.

[4] M. Amiti and S.J. Wei. Service offshoring and productivity: Evidence from the US. *The World Economy*, 32(2):203–220, 2009.

[5] R. Baldwin. Globalisation: the great unbundling (s). *Economic Council of Finland*, 20, 2006.

[6] Y. Ben-Porath. The production of human capital and the life cycle of earnings. *The Journal of Political Economy*, 75(4):352–365, 1967.

[7] J. Bhagwati, A. Panagariya, and TN Srinivasan. The muddles over outsourcing. *The Journal of Economic Perspectives*, 18(4):93–114, 2004.

[8] A.S. Blinder. How Many US Jobs Might be Offshorable? *World Economics*, 10(2):41–78, 2009.

[9] R. Crinò. Offshoring, multinationals and labour market: A review of the empirical literature. *Journal of Economic Surveys*, 23(2):197–249, 2009.

[10] R. Crinò. Service Offshoring and White-Collar Employment. *Review of Economic Studies*, 77(2):595–632, 2010.

[11] R.J.C. Daron Acemoglu et al. *Essays on International economics by Sergi Basco.* PhD thesis, Massachusetts Institute of Technology, 2010.

[12] A.V. Deardorff. The possibility of factor price equalization, revisited. *Journal of International Economics*, 36(1-2):167–175, 1994.

[13] A.V. Deardorff. A trade theorist's take on skilled-labor outsourcing. *International Review of Economics & Finance*, 14(3):259–271, 2005.

[14] N. Gregory Mankiw and P. Swagel. The politics and economics of offshore outsourcing. *Journal of Monetary Economics*, 53(5):1027–1056, 2006.

[15] G.M. Grossman and E. Rossi-Hansberg. Trading tasks: a simple theory of offshoring. *American Economic Review*, 98(5):1978–1997, 2008.

[16] A. Heshmati. Productivity growth, efficiency and outsourcing in manufacturing and service industries. *Journal of Economic Surveys*, 17(1):79–112, 2003.

[17] D. Hummels, N.R. Jørgensen, and J.R. Munch. The wage effects of offshoring: Evidence from danish matched worker-firm data. 2011.

[18] J.B. Jensen and L.G. Kletzer. Measuring tradable services and the task content of offshorable services jobs. *Labor in the New Economy*, 71:309, 2010.

[19] J.B. Jensen, L.G. Kletzer, J. Bernstein, and R.C. Feenstra. Tradable services: Understanding the scope and impact of services offshoring [with comments and discussion]. In *Brookings Trade Forum*, pages 75–133. JSTOR, 2005.

[20] G. Kambourov and I. Manovskii. Occupational mobility and wage inequality. *Review of Economic Studies*, 76(2):731–759, 2009.

[21] G. Kambourov and I. Manovskii. Occupational specificity of human capital*. *International Economic Review*, 50(1):63–115, 2009.

[22] W. Kohler. International outsourcing and factor prices with multistage production. *Economic Journal*, pages 166–185, 2004.

[23] P. Krugman. Degrees and dollars. *NYTimes. com, March*, 6:2011, 2011.

[24] K.B. Olsen. *Productivity impacts of offshoring and outsourcing: A review.* Citeseer, 2006.

[25] G. Psacharopoulos. Returns to investment in education: A global update. *World development*, 22(9):1325–1343, 1994.

[26] S. Redding and P.K. Schott. Distance, skill deepening and development: will peripheral countries ever get rich? *Journal of Development Economics*, 72(2):515–541, 2003.

[27] M. Ritter. Offshoring, trade in tasks and occupational specificity of human capital. *Manuscript, Temple Univ*, 2008.

[28] P.A. Samuelson. The transfer problem and transport costs: the terms of trade when impediments are absent. *The Economic Journal*, 62(246):278–304, 1952.

[29] D. Trefler. Service offshoring: Threats and opportunities. In *Brookings Trade Forum*, volume 2005, pages 35–60. Brookings Institution Press, 2006.

[30] D. Trefler and Canada. Industry Canada. *Policy Responses to the New Offshoring: Think Globally, Invest Locally.* Citeseer, 2006.

[31] D. Van Welsum and G. Vickery. Potential offshoring of ict-intensive using occupations. *DSTI Information Economy Report, OECD, Paris*, 2005.

7 Appendices

- APPENDIX 1.

This section links expectations regarding the ICT shock to ex-ante outcomes. Here, I do not fully characterize the equilibrium of an offshoring model with forward-looking agents. Moreover, deriving such an equilibrium might require a large departure from this setup. This paper provides a simple benchmark, describing some channels through which expectations and ex-ante outcomes are connected. Therefore, I use this benchmark to study public policy implications for a well-informed, forward-looking government.

Several authors argue that the ICT revolution requires a change in the direction of public policy in terms of two dimensions: educational policy and welfare programs. Regarding educational policy, these authors claim that providing more traditional education is not the right answer. In particular, Krugman (2011)[23] argues that college degrees do not guarantee good jobs, and Blinder (2009) claims that a college degree "may no longer be a panacea."[22] According to these authors, educational policy should instead provide students with high retraining skills and the knowledge necessary to fulfill hardly-tradeable tasks.[23] This paper shows that retraining skills are relevant and that hardly tradeable-tasks have the highest returns.

As for welfare programs, these authors claim that public policy should provide a safety net and seriously engage in retraining programs. In this section, I follow Baldwin, who argues that public policy should protect workers rather than sectors, and consider a worker-specific transfer system. Furthermore, I follow Blinder, who proposes improvements to federal job training programs, and search for a transfer system that improves the efficiency of the retraining process. Hence, I make an efficiency argument for a welfare program.

In this section, I study the transfer system used by the well-informed forward-looking government. In particular, I analyze the labor allocations that this government aims to implement. Among the feasible allocations, the Pareto efficient allocations maximize aggregate lifetime income, given tasks' total employment levels.[24] In other words, a transfer system allows the government to sort workers across tasks such that aggregate income is maximized. I next search for necessary conditions governing the sorting of workers so that the allocations are Pareto efficient. Even more importantly, these allocations represent Pareto improvements with respect to the market-induced allocations displayed in Section 3.

We are now ready to explore the analytics. For the purpose of finding the lifetime income-maximizing allocation, let me distinguish two sets of tasks. First, consider the set of tasks in which workers do not retrain. In this set, there are non-offshored tasks. Furthermore, there are offshored tasks because some of these tasks are associated with perpetual retraining plans independent of worker productivity. In

[22] Along these lines, Baldwin (2006)[5]does not think that governments should prepare students for more analytic jobs.
[23] By retraining skills I refer to the "flexibility" mentioned by these authors.
[24] By feasible allocations, I mean allocations that can be implemented through the transfer system

particular, consider workers' lifetime incomes in this set. These lifetime incomes are written as follows:

$$(42)\, I_{i,j}^{a^h,NoRet} = \frac{w_{nt,j}}{r}[1 - e^{-rT}] \;\veebar\; i \geq I_j \;\veebar\; j \,\epsilon\, (s,u)$$

$$(43)\, I_{i,j}^{a^h,NoRet} = \frac{w_j^* \beta t(i)}{r}[1 - e^{-rT}] \;\veebar\; i \leq I_j \; with\, no\, retraining \;\veebar\; j \,\epsilon\, (s,u)$$

Equation (42) refers to a worker employed in a non-offshored area, and equation (43) refers to a worker employed in an offshored area in which no worker retrains. Note that these workers' incomes do not depend on their retraining productivities.

Second, consider the set of tasks composed by the rest of the tasks, the ones in which at least one worker retrains. This set is non-empty because the government allows some retraining when maximizing aggregate income. [25] The lifetime income of any of these retrainees is written as follows:

$$(43)\, I_{i,j}^{a^h,Ret} = \frac{w^* \beta t(i)}{r} - \frac{w_{nt}}{r} e^{-rT} + [\frac{w_{nt,j} - w_j^* \beta t(i)}{r}] e^{-R_{i,j}^{a^h} * [\frac{r}{1-\rho}]}$$

$$\veebar\, i \leq I_j \; with\, retraining \;\veebar\; j \,\epsilon\, (s,u)$$

Notice in equation (43) that $\frac{dI_{i,j}^{a^h,Ret}}{da^h} > 0$: a retrainee's lifetime income rises with her retraining productivity because higher productivity reduces the duration of her plan. Therefore, worker incomes are affected by retraining productivities in the second set of tasks. Because incomes are not affected by productivities in the first set, a Pareto-improving policy is possible. In particular, the government can increase aggregate lifetime income by assigning high-productivity retraining workers to the set of retraining tasks and low-productivity retraining workers to the set of non-retraining tasks. More formally, let me state the following:

Characterization: *If a labor allocation is Pareto efficient, the workers with the lowest productivities are assigned to the tasks in which retraining does not occur. Furthermore, allocations in which these workers are assigned to non-offshored tasks and tasks with perpetual plans are weakly Pareto efficient allocations.*

Notice that moving from the Section 3 allocation to a Pareto efficient allocation affects redistribution. In particular, some of the workers with most productive retraining behavior are worse off because they are taken from non-offshored to offshored tasks. However, the transfer system allows the government to compensate these workers. In particular, the government should collect taxes from the least productive workers and transfer some of the tax revenue to the most productive employees.

[25] The reason being that workers retrain only if retraining increases their lifetime incomes.

Note that the characterization displayed above does not require any assumptions. However, the characterization does not govern the sorting of workers across the tasks in which retraining takes place. In the following, I address this issue. I investigate the conditions under which high-productivity workers should be assigned to tasks in which retraining tends to occur more often. Such tasks have large wage differentials. I refer to this property as "the decreasing monotone property" because productivity decreases as we move towards high-i tasks in these allocations. On the one hand, a government implementing these allocations raises retraining productivity in low-i-tasks, which induces a fall in the program lengths associated with these tasks.[26] On the other hand, this policy induces a decrease in productivity and an increase in plan duration in high-i-tasks. Therefore, the productivity relocation is income-maximizing if the income increase for the low-i tasks more than compensates for the income loss for the high i tasks. In other words, a decreasing monotone allocation is lifetime income-maximizing when $\frac{dI_{i,j}^{a^h,Ret}}{da^h di} < 0$.[27] Appendix 7 shows that this condition holds *if and only if*:

$$(44)\, \sigma = \frac{1}{\rho} > \frac{w_{nt,j}}{w_j^* \beta t(0)}$$

where σ measures the sensitivity of a worker's retraining expenditure to the length of his retraining plan. As understood from the learning production function displayed in (33), the sensitivity of this worker's retraining expenditure increases with this measure. Equation (44) ensures that the induced income increase in the lowest-i tasks is sufficiently large. This finding holds if the expenditures of workers employed in these tasks and thus their lifetime incomes are sufficiently sensitive to R. In particular, higher sensitivity provides more confidence that the income increase induced by a lower $R_{i,j}$ in the low-i tasks more than compensates for the income decrease induced by a higher $R_{i,j}$ in the high-i tasks.

Finally, let me comment on the transfer system that would implement the allocations mentioned in this section. This system has two goals: to ensure that every agent is better off and to incentivize workers to sort into the desired tasks. In this respect, the transfer system is suitable for broader application. For instance, an unemployment insurance system would fulfill the same goals if properly tailored. Therefore, a government that is able to determine worker productivities could tailor the system and generate Pareto improvements. An interesting question is how asymmetric information alters the efficiency of public policy in this context. As noted in the conclusion, this is a direction for further research.

- APPENDIX 2.

This Appendix shows that when Home is a large country, Home's wage rates can be solved in terms of countries' labor endowments, technologies and the transportation cost measure.When Home is a large

[26] With respect to the allocation in Section 3.
[27] -induced by a lower plan duration-

country, the relative price of the skill-intensive good must equate Home's excess supply to foreign's excess demand augmented by the transport cost measure. If consumers have identical Cobb-Douglas preferences, and considering countries' supplies given in equations $(12)-(15)$, this market-clearing condition is written as follows:

$$AL_s - \alpha\frac{I}{p^T} = \tau[\alpha\frac{I^*}{\tau p^T} - L_s^*]$$

where $I = A[p^T L_s + \tau L_u]$ and $I^* = [\tau p^T L_s^* + L_u^*]$ are countries' incomes under $(17) - (20)$ and balanced trade.

Then the relative price that solves for market clearing is:

$$p^T = [\frac{\alpha}{1-\alpha}][\frac{A\tau L_u + L_u^*}{AL_s + \tau L_S^*}]$$

; therefore:

$$w_s = A[\frac{\alpha}{1-\alpha}][\frac{A\tau L_u + L_u^*}{AL_s + \tau L_S^*}]$$

and

$$w_u = A\tau$$

- APPENDIX 3.

This appendix shows that all j-skilled tasks must have the same price in equilibrium. If there were at least one task i'_j with a strictly higher price in equilibrium, the supply of the remaining tasks would be zero. However, no demand for a task is zero, unless its price goes to infinite. Moreover, the price of tasks $i_j \neq i'_j$ cannot go to infinite, as there is at least one task i'_j with a larger price i. Consequently, there cannot be any task i'_j with a strictly higher price in equilibrium: all tasks must have the same price.

- APPENDIX 4.

This Appendix show that the equilibrium of the equilibrium is given by the intersection of the curves in Figure 1. Furthermore, this Appendix shows that if $\frac{w_s}{w_s^*} < \frac{w_u}{w_u^*}$, then $I_u^* > I_s^*$. First, evaluate the expression $\frac{w_{nt,j}(J_j)}{w_j^* \beta t(J_j)}$ in both sectors at I_u:

$$\frac{w_{nt,u}(I_u)}{w_u^* \beta t(I_u)} = e^{[\frac{ln(\frac{w_u}{w_u^*})-ln(\beta)-\int_0^{I_u} ln(t(i))}{1-I_u} - ln(t(I_u))]} = 1 > \frac{w_{nt,s}(I_u)}{w_s^* \beta t(I_u)} = e^{[\frac{ln(\frac{w_s}{w_s^*})-ln(\beta)-\int_0^{I_u} ln(t(i))}{1-I_u} - ln(t(I_u))]}$$

where the inequality for the low-skilled case comes from the definition of equilibrium and the inequality from $\frac{w_s}{w_s^*} < \frac{w_u}{w_u^*}$.

It follows from the inequality that $I_u^* \neq I_s^*$, then either $I_u^* > I_s^*$or $I_u^* < I_s^*$. To find this out, take the derivative of $\frac{w_{nt,s}(J_s)}{w_s^* \beta t(J_s)}$ with respect to J_s and find:

$$\frac{w_{nt,s}(J_s)}{w_s^* \beta t(J_s)} [\frac{ln(\frac{w_{nt,s}(J_s)}{w_s^* \beta t(J_s)})}{1-J_s} - \frac{t'(J_s)}{t(J_s)}]$$

The former term in the square brackets is negative when evaluated at at I_u because $\frac{w_{nt,s}(I_u)}{w_s^* \beta t(I_u)} < 1$. Furthermore, since $t'(J_s)$ is strictly positive, the second term is negative, as well. Therefore, we have that $\frac{\partial [\frac{w_{nt,s}(J_s)}{w_s^* \beta t(J_s)}]}{\partial J_s} \|_{J_s=I_u} < 0$. This shows that $\frac{w_{nt,s}(J_s)}{w_s^* \beta t(J_s)}$ decreases for any $J_s > I_u$; therefore, the equilibrium cannot be in this region.

Let me now prove the comparative statics results. By the implicit function theorem, we have:

$$\frac{\partial I_j}{\partial \tau} = - \frac{\left(\frac{\partial [\frac{w_{nt,,j}(J_j)}{w_s^* \beta t(J_j)}]}{\partial \tau} \right)_{\|_{J_j=I_j}}}{\left(\frac{\partial [\frac{w_{nt,,j}(J_j)}{w_s^* \beta t(J_j)}]}{\partial J_j} \right)_{\|_{J_j=I_j}}}$$

First, note that $\left(\frac{\partial [\frac{w_{nt,,j}(J_j)}{w_s^* \beta t(J_j)}]}{\partial J_j} \right)_{\|_{J_j=I_j}} < 0$

Furthermore, $\left(\frac{\partial [\frac{w_{nt,,s}(J_s)}{w_s^* \beta t(J_s)}]}{\partial \tau} \right)_{\|_{J_s=I_s}} < 0$ and $\left(\frac{\partial [\frac{w_{nt,,u}(J_u)}{w_s^* \beta t(J_u)}]}{\partial \tau} \right)_{\|_{J_u=I_u}} < 0$ proves the result on trade costs.

Moreover, $\left(\frac{\partial [\frac{w_{nt,,j}(J_j)}{w_s^* \beta t(J_j)}]}{\partial A} \right)_{\|_{J_j=I_j}} > 0$ and $\left(\frac{\partial [\frac{w_{nt,j}(J_j)}{w_s^* \beta t(J_j)}]}{\partial \beta} \right)_{\|_{J_j=I_j}} < 0$ proves the rest of results.

Finally, let me approach the equilibrium. Task-markets clear if all non-offshored tasks perceive the same wage and the wage of every offshored task equals its effective importing price. I depart from task-markets clearing in Figure 1 Equilibrium then requires two additional conditions: optimal offshoring behavior and zero profits. There is only one Point at which these conditions are jointly fulfilled. This point is the intersection of the offshoring costs and square dotted curves, denoted by I_u. Let me draw intuition on this equilibrium, for which I distinguish two regions in Figure 4.

Consider the region given by cutoff choices such that $J_u < I_u$. The square dotted curve is upward sloping and concave. Furthermore, the curve lies above the offshoring costs curve, which implies that the inequality $w_{nt,u}(J_u) > w_u^* \beta_0 t(J_u)$ holds over the whole region. Therefore, the optimal offshoring rule is not satisfied for any J_u such that $J_u < I_u$ and none of these choices is an equilibrium. In other words, offshoring costs are greater than "zero-profit wages" for any of these tasks, so firms have incentives to offshore these tasks. By doing so, companies make savings that reduce their marginal costs.

Several papers argue that offshoring creates domestic savings or, equivalently, increases firms' productivity. Hence, firms' marginal savings are positive and decreasing over this region.

Finally, consider the region defined by cutoff choices J_u such that $J_u > I_u$. As Figure 4. shows, the square dotted curve is downward sloping. If firms choose any of these tasks as their equilibrium cutoff, companies' "disavings" cause marginal costs to increase. This marginal costs rise induces a fall in the zero-profits wage, so that the zero-profits condition is restored. Furthermore, since the inequality $w_{nt,u}(J_u) < w_u^* \beta_0 t(J_u)$ holds for any of these tasks, the optimal offshoring rules are not fulfilled over this region either.

Firms' optimal offshoring rules are only fullfilled at $J_u = I_u$: for cutoffs lower than I_u, they have incentives for moving to the right and, for cutoffs greater than I_u, they have incentives for moving to the left.

This proves the result.

- APPENDIX 5.

This Appendix shows that there are more winners and fewer losers for the high-skilled case. The worker h employed in task i and sector j who earns the same wage rate with respect to the first regime is defined as follows:

$$w_j^* \beta t(i_j^h) = w_j \Longleftrightarrow \frac{w_j}{w_j^*} = \beta t(i_j^h)$$

Since we have that $\frac{w_s}{w_s^*} < \frac{w_u}{w_u^*}$, then $i_s^h < i_u^h$, there are more losers among the low-skilled workers. Furthermore, note that the relative wage on the LHS of the equation displayed above decreases with trade costs for skilled labor and increases for unskilled labor. This proves the results displayed in Figure 3 and 4.

- APPENDIX 6.

This Appendix shows that the best strategy for workers whose retraining programs are longer than T periods in the unconstrained problem is to set the duration to T. Consider the F.O.C. displayed in (36). The marginal net benefit from increasing the duration of the program is:

$$\frac{\theta w_j^* \beta t(i)}{a_h} r^{\frac{1}{\rho}} [\frac{1-\rho}{\rho}]^{-(\frac{1-\rho}{\rho})} [1 - e^{-R_{i,j}^{a^h}(\frac{r}{1-\rho})} - 1]^{-\frac{1}{\rho}} - e^{-rR_{i,j}^{a^h}} [w_{nt,j} - w_j^* \beta t(i)]$$

The two terms $\frac{\theta w_j^* \beta t(i)}{a_h} r^{\frac{1}{\rho}} [\frac{1-\rho}{\rho}]^{-(\frac{1-\rho}{\rho})} [1 - e^{-R_{i,j}^{a^h}(\frac{r}{1-\rho})} - 1]^{-\frac{1}{\rho}}$ and $e^{-rR_{i,j}^{a^h}} [w_{nt,j} - w_j^* \beta t(i)]$ are monotonically decreasing in $R_{i,j}^{a^h}$. Therefore, the marginal net benefit from enlarging the plan longer is positive for $R_{i,j}^{a^h} < R_{i,j}^{a^h*}$. Hence, the worker can keep enlarging the program and obtain a higher utility while $R_{i,j}^{a^h} < T < R_{i,j}^{a^h*}$.

- APPENDIX 7.

This appendix derives the$j$-skilled retraining cutoff task. Using equations (38) and (41), the j-skill retraining cutoff task solves the following:

$$-[\frac{1-\rho}{r\rho}] Ln[1 - \frac{r[\frac{\rho}{1-\rho}]^{1-\rho}}{[\frac{\bar{a}}{\theta}[\frac{w_{nt,j}}{w_j^* \beta t(i)} - 1]]^{\rho}}] = T[1-\rho]$$

; therefore:

$$\hat{i_j} = t'([\frac{w_{nt,j}}{w_j^* \beta}][\frac{[\frac{\bar{a}}{\theta}[1+e^{Tr\rho}]]^{\frac{1}{\rho}}}{[\frac{\bar{a}}{\theta}[1+e^{Tr\rho}]]^{\frac{1}{\rho}} + [r[\frac{\rho}{1-\rho}]^{1-\rho}]^{\frac{1}{\rho}}}])$$

- APPENDIX 8.

This Appendix shows that the increase in a worker's lifetime income induced by a higher productivity decreases with i, under condition (44). Taking derivatives, one obtains the following:

$$\frac{dI_{i,j}^{a^h,Ret}}{da^h di} = \frac{\rho\left((w_j^*\beta t(i) - w_{nt,j})r\rho - (1-\rho)(w_j^*\beta t(i) - w_{nt,j}\rho)[\frac{a^h\rho}{\theta(1-\rho)}[\frac{w_{nt,j}}{w_j^*\beta t(i)} - 1]]^{\rho} - \frac{r[\frac{\rho}{1-\rho}]^{1-\rho}}{[\frac{\bar{a}}{\theta}[\frac{w_{nt,j}}{w_j^*\beta t(i)} - 1]]^{\rho}}\right) e^{-R_{i,j}^{a^h} * [\frac{r}{1-\rho}]}}{w_j^*\beta\left(r\rho - (1-\rho)(w\beta t(i) - w_{nt,j}\rho)[\frac{a^h\rho}{\theta(1-\rho)}[\frac{w_{nt,j}}{w_j^*\beta t(i)} - 1]]^{\rho}\right)^2}$$

If condition condition (44) holds, this expression is negative for every i.