Performance Pay and Offshoring*

Elias Dinopoulos
University of Florida

Theofanis Tsoulouhas
University of California, Merced

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Abstract: In this paper, we construct a North-South general equilibrium model of offshoring, highlighting the nexus among endogenous effort-based labor productivity and the structure of wages. Offshoring is modeled as international transfer of management practices and production techniques that allow Northern firms to design and implement performance compensation contracts. Performance-pay contracts address moral hazard issues stemming from production uncertainty and unobserved worker effort. We find that worker effort augments productivity and compensation of those workers assigned to more offshorable tasks. An increase in worker effort in the South, caused by a decline in offshoring costs, an increase in worker skill or a decline in production uncertainty in the South, increases the range of offshored tasks and makes workers in the North and South better off. An increase in Southern labor force increases the range of offshored tasks, benefits workers in the North and hurts workers in the South. International labor migration from low-wage South to high-wage North shrinks the range of offshored tasks, makes Northern workers worse off and Southern workers (emigrants and those left behind) better off. Higher worker effort in the North, caused by higher worker skills or lower degree of production uncertainty, decreases the range of offshored tasks and benefits workers in the North and South.

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*Elias Dinopoulos, Department of Economics, University of Florida, Gainesville, Florida 32611-7140. E-mail: dinopoe@ufl.edu. Theofanis Tsoulouhas, The Ernest & Julio Gallo Management Program, SSHA, University of California, Merced, CA 95343. E-mail: ftsoulouhas@ucmerced.edu.

1 Introduction

An increasing number of occupations in the U.S. labor market pay workers for their performance by offering commissions, bonuses or piece-rate contracts.[1] A large fraction of these jobs face the threat of moving to low-wage countries. This threat stems primarily from dramatic improvements in information, communication and transportation technologies that have significantly increased the fragmentation of production and task offshorability. It is now possible for firms to break up the value chain, with numerous activities occurring in various countries. Components of cell phones, airplanes, personal computers and cars are being produced in various low-wage countries such as China or Mexico. Telemarketing, radiology, customer services, accounting, order processing and other business services are being provided from low-wage countries such as India.[2].

Empirical studies document substantial dispersion in management practices across establishments within industries and across countries. They also report that firms in developing countries face substantial costs of adopting better management practices, such as performance monitoring, target setting and incentive schemes.[3] Empirical studies assert that offshoring affects the wages of high and low-skilled workers and reveal that, in addition to labor productivity and wage differences between advanced and developing economies, "tradability" of tasks and occupations determines the extent and pattern of offshoring.[4]

In this paper, we construct a North-South general-equilibrium model of offshoring, highlighting the nexus among effort-based labor productivity, offshoring patterns, and the struc-

[1] Lemieux et al (2009) report that between 37 percent and 42 percent of workers in their sample were assigned to performance-pay jobs. In addition, the study finds that changes in performance-pay jobs account for most of the increase in U.S. male wage inequality above the eightieth percentile between the late 1970s and early 1990s.

[2] This phenomenon is generally referred to as "foreign outsourcing" or "offshoring." We use the latter term in this paper. See Trefler (2005) and Feenstra and Taylor (2014, Ch. 7) for additional examples.

[3] See Bloom and Van Reenen (2010), and Bloom et al (2013a, 2013b) among others.

[4] The term "tradability" refers to the ease with which a task or occupation is offshoreable. In this regard, relevant characteristics are codifiable/non-codifiable instructions and routine/non-routine occupations. Feenstra (2010) documents that offshoring reduced the wage of U.S. low-skilled (production) workers in the 1980s and raised the wage of U.S. high-skilled (non-production) workers in the 1990s. Crino (2010) asserts that, at any level of skill, offshoring has a negative impact on the level of employment in tradable occupations.

ture of wages. We view the production process as a continuum of tasks or activities, with workers being the sole factor of production. Based on the literature on performance-pay contracts, we assume that within each activity worker-specific output depends on observable skill level, unobservable effort and an unobservable idiosyncratic shock. Skill level captures all observable components of exogenous labor productivity. Worker-specific output is also observable to the manager and is used to reward worker effort via a piece-rate or absolute performance compensation contract. The contract consists of (i) a base payment, independent of output level, inducing worker participation; and (ii) a bonus payment, proportional to output level, encouraging worker effort.[5]

We incorporate the production structure in a benchmark general equilibrium framework consisting of two economies: an advanced high-wage region (the North), and a developing low-wage region (the South). Both regions produce the same final homogeneous good under perfect competition. The production structure consists of two segments producing the same homogeneous good under different technologies: the modern segment where each firm produces a continuum of offshorable tasks; and the traditional segment where tasks cannot be offshored and production must occur locally.

Driven by uncertainty, we assume that firms in the modern segment know how to design and implement incentive contracts, inducing workers to exert effort. In contrast, firms in the traditional segment lack expertise in modern management practices, resulting in workers exerting minimum effort. Production in the traditional segment is carried by small local firms and involves relatively simple production techniques that do not require quality control, sophisticated performance monitoring techniques and advanced human-resouce management practices. We model this segment by assuming that its production process is deterministic and production occurs under a diminishing returns to labor technology.

[5] In the present context, the absence of a "common" production shock (i.e., a production shock which is common among workers) makes the introduction of relative performance compensation contracts unnecessary. The main results hold whether a firm uses absolute or relative performance compensation contracts. In addition, we do not consider optimal compensation contracts to keep the analysis simple and the intuition clear.

The presence of two production segments is designed to capture, albeit in a reduced form and perhaps in an extreme way, the dispersion of managerial practices across firms within the same industry (Bloom et al (2013a)). It also serves two analytical purposes: first, the traditional segment creates a general-equilibrium channel through which offshoring affects worker reservation utility and worker welfare; and second, it allows us to model offshoring as the transfer of managerial practices (performance-pay contracts) from North to South, as discussed below.

In the absence of offshoring, we assume that the South produces the same final good using traditional (non-offshorable) technology. This assumption is made for tractability purposes and captures the stylistic fact that modern human-resource management practices including performance monitoring are used much more extensively in advanced countries than in developing countries.[6] In the absence of offshoring, no trade occurs between North and South. In this paper, offshoring is a combination of international transfer of management practices and production technology, allowing Northern modern firms to produce a fraction of tasks in low-wage South. Offshoring is associated with the design and implementation of performance-pay labor contracts. In other words, production of offshored activities becomes structurally identical to the production of the same activities in the North: workers in the South receive high-powered incentive compensation schemes and exert unobservable effort.

Based on the pioneering work of Grossman and Rossi-Hansberg (2008) we assume that Northern firms face heterogeneous offshoring costs that differ across tasks. We model offshoring costs in the standard "iceberg" fashion: only a task-specific *fraction* of offshored output "arrives" to the North.[7] In addition to standard trade costs, heterogeneous offshoring costs capture the notion that some tasks/occupations are more codifiable than others and

[6] Bloom and Van Reenen (2010) document the substantial variation of management practices across firms and countries. Based on survey data, they focus on management practices such as systematic performance monitoring, setting appropriate targets and providing incentives for good performance. They assert that multinational firms engage in international transfers of these practices.

[7] Grossman and Rossi-Hansberg (2008) incorporate offshoring costs in activity-specific unit-labor requirements of the production process. In our setting, production uncertainty and endogenous unobserved effort necessitate the modeling to offshoring costs in the traditional "iceberg" fashion. This difference is inconsequential.

thus exhibit lower offshoring costs. In sum, tasks remain in the North either because they are performed by workers in the modern segment and entail high offshoring costs (e.g., marketing and R&D); or because they are performed by firms in the traditional segment (e.g., where effort is observable, or simple compensation schemes are used).

The assumption of heterogeneous offshoring costs has two important implications. First, as in Grossman and Rossi-Hansberg (2008), it enables us to obtain an interior solution for the extent of offshoring. Second, offshoring costs have a direct effect on: (i) the bonus component of workers in the South employed in offshored tasks; (ii) endogenous effort-based productivity; and (iii) the wage structure in the South. Endogenous effort-based productivity leads to several additional features that complement the seminal analysis of Grossman and Rossi-Hansberg. For instance, workers in the South engaged in more offshorable activities exert higher effort and receive higher compensation. As a result, offshoring leads to an unequal wage-income distribution within a sector among (ex-ante) identical workers. In other words, the model predicts that offshoring increases residual wage inequality in the South.

The paper derives several novel results regarding the effects of globalization and contract structure on the range of offshored tasks and the distribution of worker compensation. First, an increase in the size of the South, measured by the number of Southern residents, augments the supply of labor and reduces their compensation without affecting worker effort. Second, the reduction in compensation increases profitability of offshored tasks and expands their range. Third, in the long-run firms earn zero profits. This requires a greater compensation and worker welfare in the North. In summary, an increase in Southern labor force expands the range of offshored tasks, hurts workers in the South, and benefits workers in the North (Proposition 2).

Where globalization takes the form of worker migration from South to North, the labor supply expands in the North and contracts in the South by the same number of workers. These supply-based effects decrease worker compensation in the North and increase worker compensation in the South without affecting worker effort in any region. Immigration shrinks the range of offshored tasks, thanks to the said compensation changes that increase profitability of tasks performed in the North, and reduce profitability of offshored tasks. Worker migration from South to North discourages offshoring, increases the welfare of Southern immigrants who receive a higher Northern wage, and increases welfare of those left behind in the South (Proposition 3).

Performance-pay contracts motivate workers to exert effort under conditions of moral hazard. As such, they reveal a novel link between parameters affecting worker effort, offshoring patterns and wages. These parameters include output uncertainty, worker skills, and the degree of absolute risk aversion. For example, an increase in worker effort in the North, caused by higher level of worker skill or lower production uncertainty, reduces the fraction of offshored tasks, increases the number of workers assigned to each task, and expands employment in the modern segment in both regions. Higher worker effort in the North makes workers better off in both regions by increasing wages thanks to the presence of offshoring (Proposition 4).

Where globalization takes the form of a reduction in offshoring costs, the productivity of workers assigned to offshored tasks increases through two channels: first, a larger fraction of offshored output arrives to the North; and second, firms offer higher bonuses inducing workers in the South to exert more effort and produce more output. Both channels work in the same direction inducing higher worker productivity, higher firm profitability, and a larger range of offshored tasks. Northern firms must earn zero profits in the long run. Excess profits based on higher productivity are eliminated by a simultaneous increase in compensation received by both Southern and Northern workers. In summary, lower offshoring costs expand the range of offshoring tasks and benefit workers in both North and South. Increasing worker skill in the South or lower production uncertainty increase worker effort in the South leading to the same general equilibrium effects as a reduction in offshoring costs (Proposition 5).

Propositions 4 and 5 complement the existing literature on offshoring by providing testable hypotheses relating patterns of offshoring and wages to measurable parameters: production uncertainty could be measured by the variance of industry-specific output; worker skill is correlated to human capital and educational characteristics; and offshoring costs can be measured by trade costs (in the case of manufacturing activities) and tradability indexes (in the case of business services). In all, the incorporation of performance-pay contacts offers new insights and expands the range of empirically-relevant determinants of offshoring patterns and wages.

The rest of the paper is organized as follows. Section 2 offers a brief overview of related studies. Section 3 presents the basic elements of the model by describing the North-South benchmark framework. Section 4 introduces task offshoring into the model. Section 5 studies the effects of globalization on offshoring and wages. Section 6 analyzes the nexus between effort and offshoring. Section 7 provides a number of concluding remarks. The algebra of various proofs is relegated to the Appendix.

2 Related Literature

The present paper proposes a simple theory of offshoring emphasizing the link between effort-based worker productivity and moral hazard. As such, it is related and contributes to several strands of literature. One strand of literature analyzes the impact of offshoring on wages (Grossman and Rossi-Hansberg (2008)), and the effects of offshoring on immigration and employment (Ottaviano et al (2013)).[8] These studies assume perfectly competitive labor markets and treat worker effort as exogenous. In contrast, our paper studies offshoring highlighting the role of imperfectly competitive labor markets, where worker effort is unobservable and worker compensation is based on piece-rate performance-pay contracts.[9] Antràs et al (2006) analyze the effects of globalization on matching between high-abilility Northern

[8] Feenstra (2010) provides an excellent literature overview.

[9] By studying offshoring within a two-good and two-factor framework, Grossman and Rossi-Hansberg highlight the effects of relative prices on wages and welfare. Our model abstracts from the "relative price" effect of offshoring because of the single-good and single-factor assumptions.

managers and low-ability Southern workers. Offshoring results in better matching leading to higher productivity and worker earnings. Our model complements their work by proposing an effort-based (as opposed to a matching) mechanism governing effects of offshoring on labor productivity.

Our paper contributes to the literature studying the interaction between trade and worker effort. Leamer (1999) and Feenstra (2010) address the interactions between trade and wages where worker productivity depends on observable effort. Brecher and Chen (2010) analyze the impact of offshoring and migration on unemployment of skilled and unskilled workers using an efficiency wage framework. In their model, high-wages are used as a discipline device to induce worker effort and lead to equilibrium unemployment, as in Shapiro and Stiglitz (1984). Our model complements this literature by studying offshoring in an environment in which firms induce more worker effort through piece-rate performance-pay contracts, and by viewing offshoring as a transfer of human resource practices from North to South.

The paper is also related to the large strand of literature incorporating effort-related incentive contracts in trade theory. For instance, Antràs (2005) studies the choice between outsourcing and FDI in a context where outsourcing entails costs associated with incomplete contracts. Grossman and Helpman (2004) apply insights of labor-contract theory to study the effects of lower trade costs on the mix between foreign direct investment (FDI) and outsourcing using a trade model with heterogeneous firms. Chen (2011) studies the tradeoff in a multinational firm's choice of organizational form where outsourcing commands information rents due to adverse selection whereas vertical integration (FDI) leads to moral hazard problems. The latter is less pronounced in capital-intensive industries and, hence, FDI is concentrated in these industries. Yu (2012) incorporates performance-pay contracts between the firm and managers in a model of heterogeneous firms and intraindustry trade to study the effects of trade liberalization on managerial compensation. Our paper contributes to this literature by analyzing the effects of globalization on offshoring and the wage structure, where the latter is the outcome of absolute performance compensation contracts offered to workers (as opposed to managers or other firms supplying intermediate inputs).

Finally, the paper delivers a new methodological contribution to the literature on performance-pay contracts (e.g., Lazear and Rozen (1981), Green and Stokey (1983), Lazear (1986), and Gibbons (1987)).[10] This literature has relied on partial-equilibrium tools, and frequently assumes that the size of a firm and reservation utility are exogenous parameters. By contrast, our model treats firm size and worker reservation utility as endogenous variables that respond to general equilibrium interactions. For example, the standard general equilibrium assumption that workers are perfectly mobile across tasks and production segments, together with the participation constraint, imply equalization of expected utility across all workers. As a result, there is a one-to-one correspondence between changes in the traditional wage and expected worker utility, providing a simple way to study the effects of parameter changes on worker welfare. Consequently, the proposed general equilibrium framework can be used to analyze other interesting issues beyond the effects of globalization.

3 The North-South Benchmark Framework

Sub-sections 3.1 and 3.2 construct the North-South benchmark framework consisting of two closed economies. In Section 4 we use this framework to analyze the impact of globalization on offshoring patterns and wages.

3.1 North

The economy in the North produces a homogeneous final good under perfect competition. Production of the final good originates in modern and traditional segments. As in Grossman and Rossi-Hansberg (2008), the modern segment produces output by combining tasks or activities. Specifically, there is a continuum of activities of measure one undertaken

[10] Also see Tsoulouhas (2015) and the references therein for more recent work.

by identical firms producing good y_m, where subscript m stands for "modern". Each task is indexed by $\theta \epsilon [0,1]$ and requires n_m workers, independently of θ. This implies that there is no substitution between inputs across tasks: the same number of workers are required to perform each task. Workers do not multi-task, e.g., a nurse cannot perform surgery or act as office manager. To produce more output, a firm may: (i) increase the number of workers n_m across all tasks; or (ii) implement performance-pay contracts to enhance worker effort and productivity. Because the measure of all tasks is one, n_m also stands for the total number of workers in the modern segment, i.e., $n_m = \int_0^1 n_m d\theta$.

Worker i, engaged in a given task θ, produces output

$$x_i(\theta) = a + e_i(\theta) + \xi_i. \tag{1}$$

Parameter a represents the level of known and observable skills (assumed to be uniform across workers and activities within a region); $e_i(\theta)$ represents worker effort; and ξ_i stands for a shock which is idiosyncratic to worker i. We assume that ξ_i is generated by an independent normal distribution $\Xi(\xi_i)$ with zero mean and finite variance $var(\xi_i) = \sigma^2, \forall\ i$.

The presence of an idiosyncratic shock ξ_i in (1) can be interpreted in two ways. First, ξ_i may capture performance evaluation errors relating to reporting or measurement. Variance σ^2 measures the degree to which firms implement and monitor performance-pay contracts: higher σ^2 implies lower managerial competence. For example, in the extreme case where $\sigma^2 \to \infty$, observed output provides no economically meaningful information. In this situation, contracts should have no bonus payments, as established below. Second, ξ_i may capture stochastic productivity shocks affecting worker output. These shocks may be related to fluctuations in learning, mood and health-related changes, or to pure luck.[11]

The informational structure of the production process is as follows: worker effort $e_i(\theta)$ and realization of production shock ξ_i are unknown to the firm and known to the worker;

[11] A more general formulation of (1), which is commonly used in the performance-pay literature, is $x_i(\theta) = a + e_i(\theta) + \xi_i + \eta$, where η is a stochastic component capturing common shocks that affect workers within a firm. For reasons mentioned earlier, we asssume that there are no common shocks.

worker skill level a and measured output $x_i(\theta)$ are known to the firm and used to design and implement the compensation contract.

Given equation (1), when a firm hires n_m workers and assigns them to the single task θ, it obtains task-specific output (e.g., component or supporting service) $y_m(\theta)$ given by

$$y_m(\theta) = \sum\nolimits_{i=1}^{n_m} x_i(\theta). \tag{2}$$

Equation (2) implies that the level of output per activity is uncertain, as it depends on the realization of production shock ξ_i. It also implies that expected value of output increases linearly with the number of workers assigned for each task n_m. In the absence of offshoring, when all tasks are performed in the North, firm output is

$$y_m = \int_0^1 y_m(\theta)d\theta = \int_0^1 \sum\nolimits_{i=1}^{n_m} x_i(\theta)d\theta. \tag{3}$$

The production process requires a few explanatory remarks. Equation (1) is standard in the literature on performance-pay contracts.[12] It also facilitates the analysis of the relationship between moral hazard and offshoring, which is missing from the existing literature.[13] Applying the *strong law of large numbers* to (3) yields $y_m = E[y_m(\theta)] = n_m E[x_i(\theta)]$, where $E[x_i(\theta)] = a + e_i(\theta)$ is the expected output per worker. Under the assumption of a continuum of tasks of measure one, firm output is deterministic and equals the expected output per task. The production function (3) exhibits constant returns to scale in the number of workers n_m for any effort level. It also implies that labor productivity is endogenous and depends positively on worker effort $e_i(\theta)$.[14]

[12] Among others, see Lazear and Rosen (1981) or Green and Stokey (1983).

[13] Grossman and Helpman (2004) apply insights of labor contract theory to the choice between outsourcing and foreign direct investment. Yu (2012) introduces piece-rate contracts for managers in a model of heterogeneous firms and intraindustry trade to study the effects of trade liberalization on managerial compensation. By contrast, this paper focuses on the effects of globalization on offshoring and on the wage structure.

[14] Equation (3) relates to production processes used in several models of endogenous growth. For example, assume that output is given by $y = H^\alpha \int_0^A [y(\theta)]^{1-\alpha} d\theta$, where H is the economy's endowment of human capital, $y(\theta)$ is the output of a typical intermediate good, and A is the measure of intermediate goods used in the production of y. Equation (3) then corresponds to the special case where $\alpha = 0$ and $A = 1$.

The two assumptions, that labor is the sole factor of production and the final good is produced under perfect competition, imply that the prevailing wage equals worker/consumer wealth. Based on the literature on performance-pay contracts, we assume that worker preferences are represented by the same CARA utility function. The utility function of worker i, assigned to task θ, is given by

$$u(w_i, e_i(\theta)) = -\exp - \left(rw_i - \frac{1}{2}\frac{r}{a}(e_i(\theta))^2 \right), \tag{4}$$

where w_i is worker wage (income), and parameter r is the coefficient of absolute risk aversion. The relationship $E[\exp(-rw_i + \frac{1}{2}\frac{r}{a}e_i^2)] = \exp[m + \frac{\sigma^2}{2}]$, where $-rw_i + \frac{1}{2}\frac{r}{a}e_i^2 \sim N(m, \sigma^2)$, delivers a closed-form solution for expected utility. Utility decreases in the coefficient of absolute risk aversion r and effort level e_i. It increases in worker income w_i, and skill level a as the latter reduces the disutility of effort.

A firm compensates worker i for exerted effort by making a "take-it-or-leave-it" offer. The offer is based on the piece-rate (absolute performance) compensation contract $w_i(\theta) = b(\theta) + \beta(\theta)x_i(\theta)$ that depends on the publicly observed output x_i.[15] Contractual parameters $b(\theta)$ and $\beta(\theta)$ denote the base payment and the piece rate (bonus) components of performance-pay contracts, respectively. The contractual parameters are determined by backward induction (as if the firm were a Stackelberg leader vis-a-vis each worker).

First, the firm calculates worker expected utility

$$E(u_i) = -\exp\left\{ -r\left[b(\theta) + \beta(\theta)[a + e_i(\theta)] - \frac{e_i(\theta)^2}{2a} - \frac{r(\beta(\theta))^2\sigma^2}{2} \right] \right\}, \tag{5}$$

[15] In this paper, we do not address questions related to optimal contract forms. Instead, we treat the contract form as exogenous. Simple linear piece rate incentive contracts are sufficient for addressing the relationship between moral hazard and offshoring. As shown below, these contracts do provide correct performance incentives to workers and sharpen the intuition of the main results.

The literature on efficiency wages has studied the effects of effort on wages, productivity, and unemployment. For example, Esfahani and Salehi-Isfahani (1989) develop a closed-economy model with a formal and an informal sector, partial observability of effort and fixed-wage contracts to study the effects of effort observarvability on economic dualism. By contrast, our paper uses a North-South framework and piece-rate contracts to study the effects of globalization on offshoring and global wage inequality.

where the expression in square brackets is worker-specific certainty-equivalent compensation. Expected utility rises with expected income and falls with effort level and variance in payments. To ensure contractual compatibility with performance incentives for workers, the firm calculates the requisite effort to maximize (5). The first-order condition

$$e_i(\theta) = a\beta(\theta) \tag{6}$$

states that worker effort depends on skill level a and piece-rate compensation $\beta(\theta)$. The firm knows that the worker chooses effort level according to (6). As a result, the firm implements desired effort level by choosing bonus $\beta(\theta)$.

Second, the firm wishes to ensure contractual compatibility with worker incentives to participate. Therefore, the firm selects the value of base payment $b(\theta)$ satisfying the individual rationality constraint. Denote with ω the wage in the traditional segment where workers exert minimum (zero) effort obtaining the (expected) reservation utility $u_i(\omega, 0)) = -\exp(-r\omega)$. Assuming perfect worker mobility between the modern and traditional segments, the individual rationality constraint is expressed as

$$E(u_i) = u_i(\omega, 0),$$

which is equivalent to

$$b(\theta) = \omega + \frac{r\sigma^2 - a}{2}(\beta(\theta))^2 - a\beta(\theta). \tag{7}$$

Equation (7) provides a general equilibrium expression for the individual rationality constraint. The firm brings about worker participation by setting the base payment $b(\theta)$ according to (7). There exists a direct relationship between traditional wage ω and base payment $b(\theta)$. As the traditional wage increases, the firm offers a higher base payment to bring about worker participation.

The firm exercises bargaining power by offering a "take-it-or-leave-it" contract to each and every potential worker. Equation (7) implies that the worker accepts the contract. Subject to worker risk tolerance and production uncertainty, the firm captures worker-effort generated surplus. The worker rationality constraint (7) ensures the application of the principle of compensating wage differentials. Independently of the structure of observed wages, all workers enjoy the same level of (expected) utility. This means that there is a one-to-one correspondence between changes in the traditional wage ω and the welfare of each worker, when the latter is measured by expected utility $E(u_i)$.

The final good is designated as the numeraire and its price is set equal to one. The modern firm's expected profit is $E(\pi_m) = E(y_m) - E\left[\int_0^1 \sum_{i=1}^{n_m} w_i(\theta)d\theta\right]$. Substituting conditions (6) and (7) into the profit expression together with algebraic calculations deliver

$$E(\pi_m) = n_m a + n_m a \int_0^1 \beta(\theta)d\theta - n\omega - n \int_0^1 \frac{a + r\sigma^2}{2}(\beta(\theta))^2 d\theta. \tag{8}$$

Maximizing (8) with respect to the bonus factor $\beta(\theta)$ yields

$$\beta(\theta) = \frac{a}{a + r\sigma^2}, \forall\theta. \tag{9}$$

Substituting (9) into (7) leads to the optimum base payment

$$b(\theta) = \omega - \frac{a^2}{2}\frac{(3a + r\sigma^2)}{(a + r\sigma^2)^2} = \omega - \frac{3a + r\sigma^2}{2}(\beta(\theta))^2, \ \forall\theta. \tag{10}$$

Given that $\beta(\theta) < 1$, the firm provides a bonus payment which equals a fraction of worker output. Condition (7) reveals the existence of an inverse relationship between the bonus and the equilibrium base payment. Bonus $\beta(\theta)$ in (9) increases with the level of worker skill a. In addition, the firm provides a lower bonus when there exists greater production uncertainty σ^2. More intense production shocks make the link between effort and output more nebulous. When the coefficient of risk aversion r is higher, the firm provides insurance to workers by lowering the bonus payment and increasing the base payment.

Given that the bonus payment depends positively on worker skill (ability) level, according to (10) more skilled workers receive a lower base payment $b(\theta)$, because more able workers need weaker incentives to participate. By contrast, the base payment depends positively on production uncertainty σ^2. Workers need greater incentives to participate when facing greater uncertainty. The base payment also depends positively on the worker's coefficient of risk aversion r. Provided that production uncertainty is sufficiently low (in particular, if $\sigma^2 < 2$), more risk-averse workers seek a greater base payment to participate.[16] Conditions (9) and (10) reveal that the optimum base payment $b(\theta) = b$, piece rate $\beta(\theta) = \beta$, as well as the optimum effort level e_i, are independent of the assigned task θ.[17]

Substituting (9) in expression (8) generates the modern firm's expected profit

$$E(\pi_m) = n_m \left[a + \frac{1}{2}\varepsilon - \omega \right], \tag{11}$$

where ε denotes the equilibrium effort level

$$\varepsilon = a\beta = \frac{a^2}{a + r\sigma^2}. \tag{12}$$

Equation (11) highlights the determinants of short-run profits for the modern firm. The term in square brackets corresponds to profits per worker and consists of three components: (i) worker skill level equaling the no-effort productivity level; (ii) the contribution of effort to net profit, as given by (12); and (iii) worker opportunity costs as measured by the traditional wage. Expected profits are proportional to the number of workers employed n_m. In summary, short-run profits rise with worker skill and number of workers employed. Short-run profits fall with the degree of risk aversion, uncertainty and traditional wage.

In the long-run, free entry into the modern segment lowers expected profits to zero, which is equivalent to setting (11) equal to zero. The zero-profit condition determines the

[16] Note that the statement $\frac{\partial b(\theta)}{\partial r} > 0$ if $\sigma^2 < 2$ is not an "if and only if" statement.

[17] By contrast, Section 4 establishes that the optimum base payment, piece rate, and the level of effort with offshoring depend on the assigned task θ.

traditional wage ω

$$\omega = a + \frac{1}{2}\varepsilon. \tag{13}$$

The traditional wage increases with worker skill level and equilibrium effort level. Substituting (13) into (10) delivers the long-run base payment

$$b = a\left[1 - \left(\frac{a}{a + r\sigma^2}\right)^2\right] = a\left[1 - \beta^2\right] > 0. \tag{14}$$

In the long-run, there is an inverse relationship between equilibrium bonus factor and base payment. The latter decreases with skill level and increases in the degree of risk aversion and uncertainty. In the modern segment, each worker puts in effort and faces uncertainty. Compensation in the modern segment, $E(w_i) = b + \beta E(x_i) = a[1 + \beta] = a[1 + a/(a + r\sigma^2)]$, is greater than compensation in the traditional segment, ω.

Output in the traditional segment is produced under the following production function

$$y_t = f(n_t) \tag{15}$$

where $f(n_t)$ is an increasing and concave function of the number of workers employed in this segment n_t, and subscript t stands for "traditional". This modeling of production segmentation captures in a simple way the presence of heterogeneity of management practices across firms within a particular industry. In other words, we assume that the traditional segment consists of firms that do not need to offer incentive contracts either because worker effort is observable or these firms face prohibitively high costs of measuring individual worker performance and thus do not offer a bonus leading to minimal worker effort. For example, Bloom et al (2013), using the Management and Organizational Practices Survey (MOPS), document the substantial dispersion of management practices across U.S. manufacturing establishments within industries and across regions. These management practices include performance monitoring, target setting, and incentive schemes.

Equation (15) implies that output in the traditional segment does not depend on individual worker effort but only on the number of workers employed. Profit maximization requires that the traditional wage ω equal the value of the marginal product of labor $\omega = \partial f(n_t)/\partial n_t$, where ω is given by (13). Concavity of the production function implies that the demand for labor in the traditional segment is a decreasing function of the wage ω, and is obtained by inverting the first-order condition for profit maximization (i.e., $n_t(\omega)$, where $\partial n_t(\omega)/\partial\omega < 0$). This property implies an endogenous general-equilibrium link between worker reservation utility and offshoring which works through the traditional wage and the full-employment condition, which is described below.[18]

Finally, we assume that the labor market is perfectly competitive. It clears and workers are fully employed. The full-employment condition is simply $n = n_m + n_t$,where n is the fixed number of Northern workers (the economy's labor endowment). Combining the full-employment condition $n = n_m + n_t$, equation (13), and the demand for labor $n_t(\omega)$ yields the following general equilibrium expression for the number of workers employed in the modern segment (and in each task)

$$n_m = n - n_t\left(a + \frac{\varepsilon}{2}\right). \tag{16}$$

Employment in the modern segment increases with the economy's number of workers n and with all parameters that raise the traditional wage ω (the latter equals the term in parenthesis), such as skill level and effort. Equation (16) implies that, unless the number of workers n is sufficiently large, the economy specializes in the traditional segment of production (i.e., $n_m = 0$). We therefore assume parameter values ensuring that the right-hand-side of (16) is strictly positive.

The general equilibrium benchmark framework makes a novel methodological contribution to the literature on performance-pay contracts. Generally speaking, this literature has

[18] One could model the traditional segment as a sector producing a different final good than the modern sector. This modeling choice would maintain the endogenous nexus among the traditional wage, base payment and worker welfare; but would introduce trade in final goods complicating the algebra and the intuition of main results.

used partial-equilibrium techniques and assumes the size of each firm and reservation utility to be exogenous parameters.[19] In contrast, our model highlights the endogenous interactions among moral hazard, firm size, worker welfare (which depends on the endogenous reservation utility) and production fragmentation.[20] The proposed general equilibrium benchmark framework can be readily used to analyze various issues beyond the effects of globalization and contract structure on offshoring patterns and wage-income distribution.

3.2 South

We conclude the presentation of the benchmark framework by considering the closed-economy equilibrium in the South. We use an asterisk to denote Southern variables and parameters. We assume that Southern firms do not have the know-how to implement and enforce performance-pay contracts in manufacturing. This is a restrictive assumption, which is made primarily for analytical purposes, and captures the stylized fact that performance-pay compensation in offshoring destination countries is uncommon. For instance, Goergen and Rennegoog (2011) review the existing literature on managerial compensation and report that bonuses constitute a negligible part of long-term compensation in India. Bloom et al (2013b) ran a field experiment in large Indian textile plants by providing free consulting managerial practices which included performance-based incentive systems for workers and managers. They argue that adoption of profitable managerial practices by Indian textile firms was hindered by informational barriers and family-based (as opposed to professional) management structure. They also report substantial consulting fees in excess of $2 million associated with the establishment of better managerial practices. Finally, Bloom and Van Reenen (2010) argue that there is a large dispersion in the quality of managerial prac-

[19] Even recent general-equilibrium models that have introduced moral hazard consideration in open economies adopt these assumptions. For instance, Grossman and Helpman (2004) present their main findings under the assumption that the agent's reservation utility is exogenous, and Vogel (2007) assumes that each team consists of two workers.

[20] Also note that given our assumption of homogeneous workers, we do not have to worry about countervailing incentives, which are present when the principal has to offer such a great deal to highly able agents in order to attract them that makes low ability agents mimic the high types.

tices across countries and that multinational firms engage in international transfers of these practices.

These empirical studies suggest that most domestic (as opposed to multinational) firms in developing countries located in manufacturing or service sectors, where offshoring is prevalent, do not typically offer performance-pay contracts to their workers. We conjecture that factors contributing to the relative low use of modern human resource management practices include absence of monitoring technologies, high level of complexity and scale of production processes, lack of experience with modern managerial practices including electronic records and quality controls, and labor market rigidities. There may also be institutional, bureaucratic, regulatory or legal impediments to the implementation of non-traditional compensation schemes, which are ameliorated only as a necessary step to attract foreign direct investment and offshoring activities.

This conjecture stands contrary to evidence from developing countries that compensation schemes such as sharecropping in agriculture or piece-rate compensation in handicraft activities have been long standing. These activities involve relatively simple and small scale production techniques that do not require quality control, complicated recording practices, and sophisticated contract enforcement and monitoring managerial techniques. Moreover, globalization has resulted in the creation of millions of privately owned firms that are more likely to use performance-pay compensation schemes. For instance, Reynolds et al (2003) report that in 2003 almost 107 million Indian entrepreneurs tried to establish 85 million start-ups, and about 100 million Chinese entrepreneurs attempted to create 56 million new firms. The expansion of self-employment and new firms in developing countries suggests that performance-pay schemes are more prevalent in the South than what our said conjecture implies.

In sum, the evidence supports the view that perfomance-pay contracts are not totally absent from developing countries and are definitely more prevalent in North than South. As a result, our assumption that South does not have the ability to adopt and implement performance-pay schemes is strong, but provides tractability and captures the dispersion in the use of these schemes between the two regions.[21]

In the absence of offshoring, the South produces final output y^* with $y_t^* = f^*(n_t^*)$, where n_t^* is the number of workers employed in the South. All markets are perfectly competitive and the full employment condition requires $n^* = n_t^*$, where n^* is the Southern labor endowment, measured by the fixed number of Southern workers. Southern final output is given by $y_t^* = f^*(n^*)$, and Southern wage is given by $\omega^* = \partial f^*(n^*)/\partial n^*$. This concludes the benchmark analysis.

4 Offshoring

We assume that modern firms in the North are able to offshore all or part of their activities. We do not consider whether offshoring occurs on an arms length or non-arms length basis. The reader may apply the main assumptions and results of the model to the situation where Northern multinationals employ Southern workers for offshored activities. For example, the model applies to Verizon establishing a wholly-owned subsidiary in Bangalore, and employing Indian programmers to create software for Verizon's operations in the U.S. The model also applies to Cisco and General Electric opening wholly-owned research centers in Bangalore.[22]

Our model views offshoring as the transfer of certain management practices from the North to the South. In terms of outcomes, this is equivalent to an international transfer of technology. Bloom and Van Reenen (2010) present survey evidence on the variation in management practices of firms in different countries, as well as on how these practices account for a substantial part of productivity differences. They also assert that multinationals use

[21] Strong assumptions fascilitating the tractability of the analysis are common in the literature of North-South trade. For instance, the theory of North-South trade and growth routinely assumes that Southern firms can only imitate products discovered in the North instead of discovering new products. See Segerstom et al (1990) and Helpman (1993) among many others.

[22] Trefler (2005) provides an excellent discussion of offshoring as well as examples. This paper complements the study of Grossman and Helpman (2004) which analyzes the effects of managerial incentives on the choice between arms length and non-arms length offshoring.

better management practices than local firms, and transfer the same practices abroad. In this paper, we focus on a specific aspect of management practices: piece-rate performance contracts.

When production is offshored, a worker in the South engaged in an offshored task θ produces output

$$x_i^*(\theta) = a^* + e_i^*(\theta) + \xi_i^*, \tag{17}$$

where parameter a^* stands for a Southern worker's known skills; $e_i^*(\theta)$ denotes worker effort in the South; and ξ_i^* denotes an idiosyncratic shock which follows an independent normal distribution $\Xi(\xi_i^*)$ with zero mean and finite variance $var(\xi_i^*) = \sigma^{*2}, \forall\ i$. Parameter a^*, a generic term, is the deterministic component of labor productivity in the South. Generally speaking, labor productivity depends on the state of technology, innate skills, human and physical capital etc. The idiosyncratic shock ξ_i^* can be viewed as a production shock or a performance measurement error.

We assume the following throughout the paper:

Assumption 1 *The skill level of a worker in the North is greater than that of one in the South, $a > a^*$; and the variance in production of an offshored task is greater than the variance of a non-offshore*d *task, $\sigma^{*2} > \sigma^2$.*

Assumption 1 facilitates the interpretation and intuition underlying the main results. It states that a worker in the North is likely more productive than in the South.

Where tasks $\theta \in [\overline{\theta}, 1]$ are offshored, total output of a modern Northern firm is given by

$$y_m \mid \overline{\theta} = \int_0^{\overline{\theta}} \sum_{i=1}^{n_m} x_i(\theta) d\theta + \int_{\overline{\theta}}^1 \sum_{i=1}^{n_m} \lambda\phi(\theta) x_i^*(\theta) d\theta. \tag{18}$$

The term on the right-hand-side of equation (18) corresponds to intermediate output produced by tasks located in the North, where $x_i(\theta)$ is given by (1), as explained earlier in the paper. The second term corresponds to intermediate output produced by offshored activities.

A worker in the South engaged in activity θ produces $x_i^*(\theta)$ units of intermediate output. The term $\lambda\phi(\theta)$ captures the "offshorability" of activity θ: for each unit of intermediate output produced in the South, $\lambda\phi(\theta)$ "arrives" i.e., can be used productively, in the North.

Assumption 2 *Parameter* λ *and function* $\phi(\theta)$ *are such that* $0 \leq \lambda\phi(\theta) \leq 1$; $\phi(0) = 0$; $\phi(1) = 1$; *and* $d\phi(\theta)/d\theta > 0$, $\forall\theta$.

This assumption governs offshoring costs. It holds true for the class of functions $\phi(\theta) = \theta^\gamma$, where γ is a positive constant. It also provides sufficient conditions for non-negative offshoring costs. The term $\phi(\theta)$ is an increasing function of θ implying that higher values of θ are associated with lower offshoring costs and higher task-specific productivity in the South. The term λ is a shift parameter. An increase in λ may be interpreted as technological improvements in transportation, communication, and monitoring technologies, bringing about a reduction in offshoring costs.[23] The assumption that the costs of offshoring vary across activities is similar to the one employed by Grossman and Rossi-Hansberg (2008) and serves the same purpose: it delivers an interior solution to the fraction of offshored activities and simplifies the comparative static analysis.[24]

Equation (18) assumes that, no matter where production occurs, there exists no substitution of workers among activities. In other words, in both the North and South, firms must use the same number of workers per activity n_m. This assumption captures, albeit in an extreme way, the complementarity of production factors used across activities in a firm. For example , if Citibank Mastercard doubles its U.S.-based labor force for processing operations, it would likely double the labor force for its call center located in India.[25] Finally, in

[23] Lower transportation costs and improved communications have enabled managers to better control foreign operations. Prior to 1970, there was no fax or e-mail, no internet, and no teleconferencing. Transportation costs, in the interim, have declined as a result of larger containers, barges and airplanes.

[24] Grossman and Rosi-Hansberg (2008) assume that offshoring requires different amounts of activity-specific labor to produce one unit of intermediate output. In this paper, we adopt the "iceberg" trade-cost assumption to model offshoring costs.

[25] Even if the number of workers is the same across activities, the combination of endogenous effort and heterogeneous offshoring costs implies that output differs across activities. In addition, according to Grossman and Rossi-Hansberg (2008), an activity requiring a team twice as large as another activity maybe considered as two identical activities.

the absence of offshoring (that is, if $\overline{\theta} = 1$), equation (18) becomes identical to equation (3).

The utility function $u(w_i^*, e_i^*(\theta)) = -\exp - \left(rw_i^* - \frac{1}{2}\frac{r}{a^*}(e_i^*(\theta))^2\right)$, where w_i^* is the compensation to worker i, represents worker preferences in the South. As in the benchmark framework, workers in the North get compensated based on a piece-rate contract $w_i(\theta) = b(\theta) + \beta(\theta)x_i(\theta)$. Similarly, workers in the South who engaged in offshored activities get compensated based on the piece-rate contract $w_i^*(\theta) = b^*(\theta) + \beta^*(\theta)x_i(\theta)$. Using backward induction, the Northern firm calculates the contractual parameters $[b(\theta), \beta(\theta)]$ and $[b^*(\theta), \beta^*(\theta)]$, as follows. First, the firm calculates the expected utility of a worker and determines the optimal effort level. The base payment, $b(\theta)$ or $b^*(\theta)$, is determined by the relevant participation constraint which ensures that a worker is indifferent between the traditional and the modern segment in each region. Second, the firm calculates the optimal bonus factors $\beta(\theta)$ and $\beta^*(\theta)$; and third, the principal chooses the optimal fraction of offshored activities $\overline{\theta}$. Finally, in the long run, perfect competition ensures that free entry drives global expected profits to zero.

The expected global profits of a typical Northern firm in the modern segment can be expressed as $E[\pi^G(\overline{\theta})] = E[\pi(\overline{\theta})] + E[\pi^*(\overline{\theta})]$, where $E[\pi(\overline{\theta})] = E[\int_0^{\overline{\theta}} \sum_{i=0}^{n_m}(x_i(\theta) - w_i(\theta))d\theta]$ is the Northern component and $E[\pi^*(\overline{\theta})] = E[\int_{\overline{\theta}}^1 \sum_{i=0}^{n_m}(\lambda\phi(\theta)x_i^*(\theta) - w_i^*(\theta))d\theta]$ is the Southern component of global profits. For any given value of $\overline{\theta}$, equations (6) and (7), respectively, express Northern worker effort and base payment. Using the same methodology as in the benchmark model, we can express the Northern component of global profits as

$$E[\pi(\overline{\theta})] = \overline{\theta}n_m a + n_m a \int_0^{\overline{\theta}} \beta(\theta)d\theta - \overline{\theta}n_m\omega - n_m \int_0^{\overline{\theta}} \frac{a + r\sigma^2}{2}(\beta(\theta))^2 d\theta. \tag{19}$$

Maximizing equation (19) with respect to the bonus factor $\beta(\theta)$ yields equation (9). Substituting equation (9) into (19) provides the following expression for the Northern component of global expected profits

$$E[\pi(\overline{\theta})] = \overline{\theta}n_m \left[a + \frac{\varepsilon}{2} - \omega\right]. \tag{20}$$

Equations (6), (9), and (10) express equilibrium effort level, bonus factor and base payment in the North, respectively. Even with offshoring, these equilibrium levels continue to be the same as in the benchmark model. Expected profit in the North $E[\pi(\overline{\theta})]$, however, is now proportional to the fraction of tasks $\overline{\theta}$ assigned to Northern workers.

We then determine the optimal piece-rate contract offered to workers in the South and derive the Southern component of global profits. Using backward induction, again, the firm first calculates Southern worker expected utility, which is similar to (5). To ensure contract compatibility with worker incentives, the firm then calculates the effort level that maximizes expected worker utility. This maximization yields

$$e_i^*(\theta) = a^*\beta^*(\theta). \tag{21}$$

To ensure contract compatibility with worker decision to participate, the firm chooses the value of base payment $b^*(\theta)$ satisfying the individual-rationality (participation) constraint with equality. As a result, workers receive no rents and still accept the contract.

Denote with ω^* the Southern wage in the traditional segment, where workers exert minimum (zero) effort and receive expected reservation utility $u(\omega^*, 0) = -\exp(-r\omega^*)$. The individual-rationality constraint implies a condition similar to (7), and can be expressed as

$$b^*(\theta) = \omega^* + \frac{r\sigma^{*2} - a^*}{2}(\beta^*(\theta))^2 - a^*\beta^*(\theta). \tag{22}$$

By choosing piece rate $\beta^*(\theta)$, the Northern firm determines Southern worker effort because a Southern worker optimally sets his effort according to (21). In addition, by setting $b^*(\theta)$ according to (22), the Northern firm ensures worker participation in offshored activities at least cost.

Conditions (21) and (22) imply that expected profit from offshored activities, $E[\pi^*(\overline{\theta})] =$

$\int_{\overline{\theta}}^{1} \sum_{i=0}^{n_m} \lambda\phi(\theta) E[x_i^*(\theta)]d\theta - \int_{\overline{\theta}}^{1} \sum_{i=0}^{n_m} E[w_i^*(\theta)]d\theta$, can be expressed as

$$E[\pi^*(\overline{\theta})] = n_m a^* \lambda \int_{\overline{\theta}}^{1} \phi(\theta)d\theta + n_m a^* \lambda \int_{\overline{\theta}}^{1} \phi(\theta)\beta^*(\theta)d\theta - n_m \omega^*(1-\overline{\theta}) - n_m \int_{\overline{\theta}}^{1} \frac{a^* + r\sigma^{*2}}{2}(\beta^*(\theta))^2 d\theta. \tag{23}$$

Maximizing (23) with respect to $\beta^*(\theta)$ provides the optimal bonus factor for Southern workers

$$\beta^*(\theta) = \frac{\lambda\phi(\theta)a^*}{a^* + r\sigma^{*2}}. \tag{24}$$

Substituting equation (24) into (21) provides an expression for the optimal activity-specific effort exerted by a Southern worker

$$\varepsilon^*(\theta) = \frac{\lambda\phi(\theta)a^{*2}}{a^* + r\sigma^{*2}}. \tag{25}$$

Assumption 2 implies that: (i) the bonus offered to Southern workers is merely a fraction of reported output, i.e., $\beta^*(\theta) < 1$; and (ii) the equilibrium effort level in the South is less than skill level a^*, i.e., $\varepsilon^*(\theta) < a^*$.[26] Unlike Northern workers, Southern workers receive a bonus $\beta^*(\theta)$ that depends on task at hand θ. This bonus increases with the "offshorability" of each activity, captured by term $\lambda\phi(\theta)$. Assumption 2 also implies that the optimal bonus factor $\beta^*(\theta)$ and effort $\varepsilon^*(\theta)$ increase monotonically in θ. Southern workers employed in more "offshorable" activities receive higher bonuses and exert greater effort. In contrast, equations (6) and (9) imply that the optimal effort level and bonus factor are identical across all tasks located in the North.[27]

Reduced transportation, communication, coordination and monitoring costs (measured by a higher λ) raise optimal bonus and effort level of workers in the South. A Southern worker with higher skill level a^* receives a higher bonus; and receives a lower bonus in

[26] If there are no activity-specific offshoring costs, i.e., $\lambda\phi(\theta) = 1$, then equations (24) and (25) yield the corresponding expressions for bonus and effort in the North.

[27] If workers in the South had the same ability as workers in the North and faced the same uncertainty, i.e., $a^* = a$ and $\sigma^{*2} = \sigma^2$, then Southern workers would receive a lower bonus for the same task θ, i.e., $\beta^*(\theta) < \beta(\theta)$.

the presence of higher uncertainty σ^{*2} or a greater risk aversion coefficient r. Uncertainty weakens the link between effort and observed output. As a result, workers with greater risk aversion receive a larger base payment and therefore greater insurance against production uncertainty.

The optimal base payment offered to workers employed in offshored activities can be calculated by substituting equation (24) into equation (22), and using equation (25)

$$b^*(\theta) = \omega^* - \frac{\varepsilon^*(\theta)}{2(a^* + r\sigma^{*2})}[2(a^* + r\sigma^{*2}) - \lambda\phi(\theta)(r\sigma^{*2} - a^*)], \ \forall\theta. \tag{26}$$

Equation (26) indicates that the firm offers a smaller activity-specific base payment $b^*(\theta)$ than the traditional wage ω^*. There also exists an inverse relationship between base payment and skill level a. Skilled workers need less incentives to participate. By contrast, there exists a positive relationship between base payment and production uncertainty σ^{*2}. Workers need higher participation incentives in the face of greater uncertainty, provided that $\sigma^{*2} > 1/2$.[28] There also exists a positive relationship between base payment and a worker's coefficient of risk aversion r. When worker skill level is sufficiently high, i.e., when $a^* >> r\sigma^{*2}$, more risk-averse workers need greater incentives to participate.[29] More skilled workers rely less on the base payment than the bonus factor. However, greater risk-aversion reduces the bonus factor and requires an adjustment in the base payment.

Lower offshoring costs, captured by higher parameters λ and $\phi(\theta)$, have an ambiguous effect on the optimal base payment. They lower the base payment where worker skill is sufficiently high, i.e., if $a^* \geq r\sigma^{*2}$. They have an ambiguous effect on the base payment where worker skill level is sufficiently low, i.e., if $a^* < r\sigma^{*2}$. Finally, they increase the base payment where worker skill level is very low, i.e., $a^* << r\sigma^{*2}$.[30]

[28] If $\sigma^{*2} < 1/2$, the relationship between the base payment and the variance of output would depend on parameter values; in this respect, $\sigma^{*2} > 1/2$ is a reasonable regularity condition.

[29] This result depends on parameter values where worker skill level is low, i.e., if $a^* < r\sigma^{*2}$.

[30] The intuition behind this result is that where worker skill level in the South is high, workers put more weight on bonus relative to base payment. In this case, a decline in offshoring costs that increases offshorability of all tasks reduces the base payment and increase the bonus factor. By contrast, where worker skill level is sufficiently low, disutility of effort is high. Workers employed in more offshorable activities receive a

Substituting equation (24) into (**??**) provides an expression for profits from offshored tasks

$$E[\pi^*(\overline{\theta})] = n_m \int_{\overline{\theta}}^{1} \left[a^* \lambda \phi(\theta) + \frac{[\lambda \phi(\theta) a^*]^2}{2(a^* + r\sigma^{*2})} - \omega^* \right] d\theta. \tag{27}$$

Profits from offshored tasks increases with the number of workers assigned to each task n_m, worker skill level a^*, relatively lower offshoring costs (measured by a higher $\lambda\phi(\theta)$), and the measure of offshored tasks $1 - \overline{\theta}$. Profits from offshored tasks decrease with production uncertainty σ^{*2} and traditional wage ω^*.

We next determine the optimal fraction of offshored activities $\overline{\theta}$ so as to maximize expected global profits $E[\pi^G(\overline{\theta})] = E[\pi(\overline{\theta})] + E[\pi^*(\overline{\theta})]$, where $E[\pi(\overline{\theta})]$ is given by (20) and $E[\pi^*(\overline{\theta})]$ is given by (27). Maximizing

$$E[\pi^G(\overline{\theta})] = \overline{\theta} n_m \left[a + \frac{1}{2} \frac{a^2}{a + r\sigma^2} - \omega \right] + n_m a^* \lambda \int_{\overline{\theta}}^{1} \phi(\theta) d\theta + \frac{1}{2} n_m a^{*2} \lambda^2 \int_{\overline{\theta}}^{1} \frac{[\phi(\theta)]^2}{a^* + r\sigma^{*2}} d\theta - n_m \omega^* (1 - \overline{\theta}) \tag{28}$$

with respect to $\overline{\theta}$ yields

$$a + \frac{\varepsilon}{2} - \omega = \lambda \phi(\overline{\theta}) \left[a^* + \frac{\varepsilon^*(\overline{\theta})}{2} \right] - \omega^*. \tag{29}$$

The optimal level of worker effort in the North ε is given by equation (12). The optimal levels of worker effort in the South $\varepsilon^*(\overline{\theta})$ are given by equation (25).[31] The left-hand-side of (29) corresponds to expected profitability of any task θ located in the North, and the right-

higher bonus and a higher base payment. A higher bonus does not compensate sufficiently for utility loss, given that less skilled workers care more about base payment than the bonus factor.

[31] Equation (29) is derived by differentiating (28) with respect to $\overline{\theta}$ to obtain

$$\left[a + \frac{1}{2} \frac{a^2}{a + r\sigma^2} - \omega \right] + a^* \lambda \frac{d \int_{\overline{\theta}}^{1} \phi(\theta) d\theta}{d\overline{\theta}} + \frac{a^{*2} \lambda^2}{2(a^* + r\sigma^{*2})} \frac{d \int_{\overline{\theta}}^{1} [\phi(\theta)]^2 d\theta}{d\overline{\theta}} + \omega^* = 0$$

and, then, using the Leibniz integral rule. Assumption $d\phi(\overline{\theta})/d\overline{\theta} > 0$ guarantees uniqueness of $\overline{\theta}$ and satisfaction of the second-order condition for profit maximization

$$d^2 E[\pi^G(\overline{\theta})]/d\overline{\theta}^2 = - \left[a^* \lambda + \frac{(\lambda a^*)^2 \phi(\overline{\theta})}{2(a^* + r\sigma^{*2})} \right] \frac{d\phi(\overline{\theta})}{d\overline{\theta}} < 0.$$

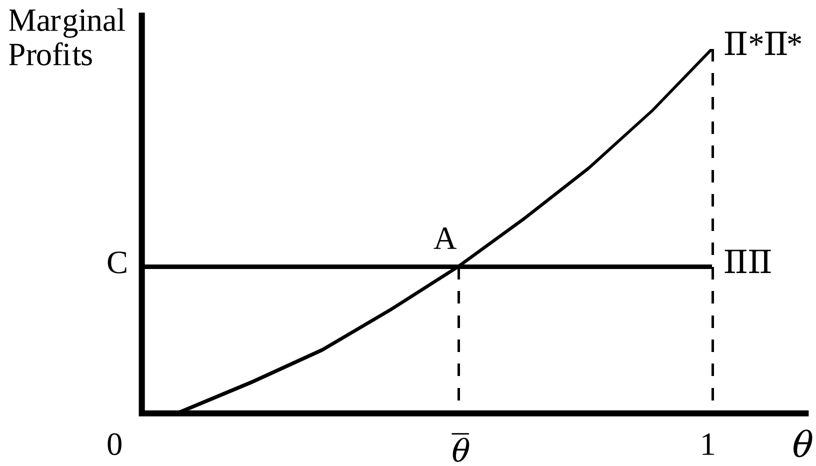

Figure 1: Short-run Equilibrium

hand-side corresponds to expected profitability of marginal task $\overline{\theta}$ located in the South. In other words, the firm chooses the allocation of tasks between North and South such that the profitability of the marginal task θ is the same across the two regions. We assume for now that traditional wages in the North and South ω and ω^* are sufficiently low, such that all tasks contribute positively to global profits (i.e., both sides of equation (29) are positive). In this case, the firm undertakes all tasks $\theta \in [0, 1]$.

Figure 1 illustrates the determination of $\overline{\theta}$ by assuming $\phi(\theta) = \theta$. Provided that $d\phi(\theta)/d\theta > 0$, the results generally apply. The horizontal line $\Pi\Pi$ is the graph of the left-hand-side of equation (29) and curve $\Pi^*\Pi^*$ is the graph of the right-hand-side. Curve $\Pi^*\Pi^*$ increases with θ and intersects line $\Pi\Pi$ at a unique interior point A, which determines the fraction of tasks located in the North $\overline{\theta}$. All tasks $\theta \in [0, \overline{\theta})$ are performed in the North because their contribution to expected global profits is higher than had they been offshored. All remaining tasks $\theta \in (\ \overline{\theta}, 1]$ are offshored. Offshorability increases with θ by way of assumption. As a result it is more profitable to offshore tasks indexed by a higher θ.

Assumptions 1 and 2 jointly guarantee that some tasks are always located in the North. Where the North-South wage gap $\omega - \omega^*$ is sufficiently large, some tasks would be offshored to the South. If ω is equal to ω^*, then Assumptions 1 and 2 imply that $a + \frac{\varepsilon}{2} > \lambda(a^* + \frac{\varepsilon^*(1)}{2})$.

In this case, all tasks are located in the North.[32]

Figure 1 can also be used to illustrate the short-run determinants of offshoring. Global profits per worker employed by a Northern firm engaging in offshoring equal area $OCA\Pi^*\Pi^*1$. Factors that reduce the left-hand-side of equation (29), such as an increase in the traditional wage received by workers in the North, a reduction in worker skill level in the North, or a reduction in effort level exerted by workers in the North, shift curve $\Pi\Pi$ lower and raise the fraction of offshored tasks, $1-\overline{\theta}$. Similarly, an increase in worker skill in the South, a decrease in offshoring costs or an increase in worker effort in the South shift curve $\Pi^*\Pi^*$ up, and raise the fraction of offshored activities $1-\overline{\theta}$. The fraction of offshored tasks is independent of the number of workers assigned to each task. The following proposition summarizes these findings.

Proposition 1 *In the short run, the fraction of offshored activities* $1-\overline{\theta}$*:*
(i) increases with Northern traditional wage ω*, Northern production uncertainty* σ^2*, Southern worker skill* a^* *and with reductions in offshoring costs captured by a higher* $\lambda\phi(\theta)$*;*
(ii) decreases with Southern traditional wage ω^**, Southern production uncertainty* σ^{*2} *and Northern worker skill* a*.*

What are the long-run determinants of offshoring? In the long run, firms earn zero expected global profits

$$E[\pi^G(\overline{\theta})] = \overline{\theta} n_m \left(a + \frac{\varepsilon}{2} - \omega\right) + n_m \int_{\overline{\theta}}^{1} \left[\lambda\phi(\theta)a^* + \frac{\lambda\phi(\theta)\varepsilon^*(\theta)}{2} - \omega^*\right] d\theta = 0. \qquad (30)$$

The zero-profit condition (30) and the first-order condition (29) can be combined to express the traditional wage in the South ω^* as a function of marginal task $\overline{\theta}$

$$\omega^*(\overline{\theta}) = \overline{\theta}\left[\lambda\phi(\overline{\theta})a^* + \frac{\lambda\phi(\overline{\theta})\varepsilon^*(\overline{\theta})}{2}\right] + \int_{\overline{\theta}}^{1} \left[\lambda\phi(\theta)a^* + \frac{\lambda\phi(\theta)\varepsilon^*(\theta)}{2}\right] d\theta. \qquad (31)$$

[32] We can relax Assumption 2 and identify parameter values under which all activities are offshored to the South. For example, this possibility arises where both $\lambda\phi(0) > 0$ and the North-South outside wage gap $\omega - \omega^*$ are sufficiently high such that the vertical intercept of curve $\Pi^*\Pi^*$ is greater than the vertical intercept of curve $\Pi\Pi$ in Figure 1.

Substituting $\omega^*(\overline{\theta})$ into (30) provides the following expression for the traditional wage in the North ω as a function of marginal task $\overline{\theta}$

$$\omega(\overline{\theta}) = \left(a + \frac{\varepsilon}{2}\right) - (1-\overline{\theta})\left[\lambda\phi(\overline{\theta})a^* + \frac{\lambda\phi(\overline{\theta})\varepsilon^*(\overline{\theta})}{2}\right] + \int_{\overline{\theta}}^{1}\left[\lambda\phi(\theta)a^* + \frac{\lambda\phi(\theta)\varepsilon^*(\theta)}{2}\right]d\theta. \quad (32)$$

Differentiating $\omega^*(\overline{\theta})$ with respect to $\overline{\theta}$ provides

$$\frac{\partial\omega^*}{\partial\overline{\theta}} = \overline{\theta}\lambda\frac{d\phi(\overline{\theta})}{d\theta}[a^* + \varepsilon^*(\overline{\theta})] > 0,\ \forall\overline{\theta} > 0. \quad (33)$$

Equation (33) establishes a direct relationship between the fraction of tasks performed in the North $\overline{\theta}$ and the traditional wage in the South ω^*. This relationship is consistent with Proposition 1 stating that an increase in the traditional wage in the South decreases the profitability of offshored tasks, discouraging Northern firms from offshoring additional tasks to the South.[33]

Moving next to equation (32). Differentiating $\omega(\overline{\theta})$ with respect to $\overline{\theta}$ yields

$$\frac{\partial\omega}{\partial\overline{\theta}} = -(1-\overline{\theta})\lambda\frac{d\phi(\overline{\theta})}{d\overline{\theta}}[a^* + \varepsilon^*(\overline{\theta})] < 0,\ \forall\overline{\theta} < 1. \quad (34)$$

An increase in the fraction of tasks performed in the North $\overline{\theta}$ requires a lower traditional wage ω.[34]

In the presence of offshoring, the full-employment condition in the North becomes $n = \overline{\theta}n_m + n_t(\omega)$, where the demand for labor in the traditional segment $n_t(\omega)$ decreases in its argument ($\partial n_t(\omega)/\partial\omega < 0$). Similarly, the full-employment condition in the South becomes $n^* = (1-\overline{\theta})n_m + n_t^*(\omega^*)$, where the demand for labor in the traditional segment $n_t^*(\omega^*)$ decreases in its argument ($\partial n_t^*(\omega^*)/\partial\omega^* < 0$). These two full-employment conditions together with equations (31) and (32) constitute a system of four independent equations with four

[33] In addition, notice that $\omega^*(0) = \int_0^1 [\lambda\phi(\theta)a^* + \lambda\phi(\theta)\varepsilon^*(\theta)/2]\, d\theta < \omega^*(1) = \lambda[a^* + \varepsilon^*(1)/2]$ because $\int_0^1 [\lambda\phi(\theta)a^* + \lambda\phi(\theta)\varepsilon^*(\theta)/2]\, d\theta < \int_0^1 \lambda[a^* + [\varepsilon^*(1)]/2]d\theta = \lambda[a^* + \varepsilon^*(1)/2]$.

[34] Equations (31) and (32) imply that that $\omega(0) = a + \varepsilon/2 + \omega^*(0) > \omega(1) = a + \varepsilon/2$.

unknowns, ω, ω^*, n_m and $\overline{\theta}$. Substituting equations (32) and (31) into the full-employment conditions for the North and South, respectively, provides

$$n = \overline{\theta} n_m + n_t[\omega(\overline{\theta})], \tag{35}$$

$$n^* = (1 - \overline{\theta}) n_m + n_t^*[(\omega^*(\overline{\theta})]. \tag{36}$$

The resulting full-employment conditions (35) and (36) determine the general equilibrium values of the fraction of tasks performed in the North $\overline{\theta}$, and the number of workers employed in each activity n_m. Equation (35) defines an inverse relationship between the number of workers assigned to each task n_m and the fraction of tasks located in the North $\overline{\theta}$. An increase in n_m creates excess demand for labor in the North. This excess demand must be offset by a reduction in $\overline{\theta}$, given that $[\partial n_t(\omega)/\partial\omega][\partial\omega/\partial\overline{\theta}] > 0$. Equation (36) defines a positive relationship between n_m and $\overline{\theta}$. An increase in n_m creates excess demand for labor in the South. This excess demand is eliminated by an increase in $\overline{\theta}$, given that $[\partial n_t^*(\omega^*)/\partial\omega^*][\partial\omega^*/\partial\overline{\theta}] < 0$.

Figure 2 illustrates the long-run general equilibrium solution. Let us first consider the upper panel. Negatively-sloped curve NN is the graph of full-employment condition in the North (35) in the n_m and $\overline{\theta}$ space. It approaches infinity as $\overline{\theta}$ approaches zero, and the autarky level of n_m as $\overline{\theta}$ approaches one. The positively-sloped curve SS is the graph of full-employment condition in the South (36). It has a positive vertical intercept for sufficiently large values of n^* and approaches infinity as $\overline{\theta}$ approaches one. The unique intersection of NN and SS curves, at point A, determines the equilibrium value of n_m, that corresponds to point C, and $\overline{\theta}$. Area $\overline{\theta}AD1$ illustrates the equilibrium number of offshored jobs $(1- \overline{\theta})n_m$.

Let us consider next the lower panel of Figure 2. The two negatively-sloped curves W^*W^* and WW are graphs of equations (31) and (32), respectively. They determine the Southern and Northern traditional wages $\omega^*$and ω for a given value of $\overline{\theta}$. The vertical distance between the two curves depicts the North-South wage gap $\omega - \omega^*$. This gap reaches

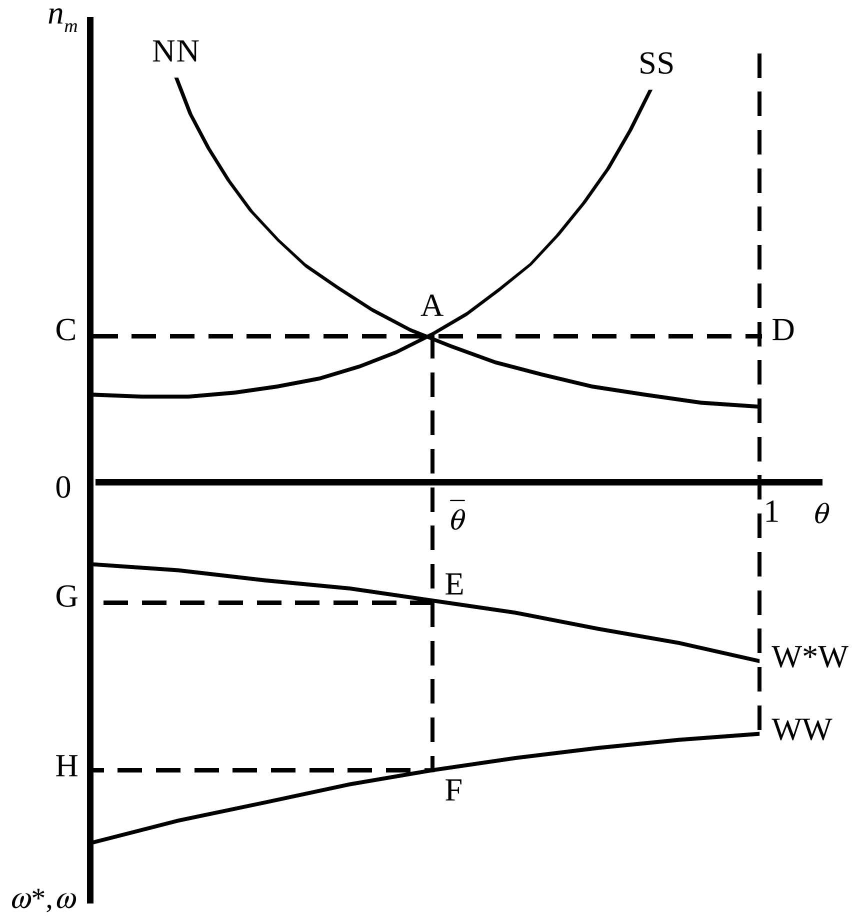

Figure 2: Long-run Equilibrium

its maximum if all tasks are offshored ($\overline{\theta} \rightarrow 0$), and its minimum if all tasks are performed in the North ($\overline{\theta} \rightarrow 1$).[35] The two intersection points between curves W^*W^* and WW and the vertical line passing through A determine the general equilibrium values of ω^* and ω, corresponding to points G and H, respectively. The North-South wage gap equals segment EF.

Offshoring affects the observed distribution of earnings within each region. Under piece-rate labor contracts, total compensation is a linear function of observed output. Hence, it inherits the stochastic properties of production shocks.[36] Let us first consider the structure of worker earnings in the North. Workers employed in the traditional segment exert no effort and receive base payment ω. By contrast, workers employed in the modern segment receive expected earnings

$$E[w_i(\theta)] = \omega + \frac{a^2}{2(a + r\sigma^2)} = \omega + \frac{\varepsilon}{2}. \tag{37}$$

The average (expected) wage of a worker employed in the modern sector in the North is higher than the traditional wage ω. It increases with worker effort level ε and is identical across all tasks in the North. Workers with higher levels of education or skill a earn higher wages, given that equilibrium effort level increases with skill.

Similar considerations apply to the equilibrium structure of earnings in the South. Workers employed in the traditional segment receive a base payment equal to ω^* and exert no effort. A Southern worker employed in offshored task θ exerts effort and receives the following average (expected) compensation

$$E[w_i^*(\theta)] = \omega^* + \frac{[\lambda\phi(\theta)a^*]^2}{2(a^* + r\sigma^{*2})} = \omega^* + \lambda\phi(\theta)\frac{\varepsilon^*(\theta)}{2}. \tag{38}$$

Equation (38) states that the expected compensation received by workers in the South as-

[35] Equation (32) implies that $\omega(1) = a + \varepsilon/2$, i.e., the Northern traditional wage reaches its autarky level. In addition, equation (31) yields $\omega^*(1) = \lambda[a^* + \varepsilon^*(1)/2] < \omega(1)$ due to Assumption 1.

[36] Specifically, the modern segment payment in the North is normally distributed with mean $\omega + \varepsilon/2$ and variance ε^2/a^2; and the modern segment compensation for task θ in the South is normally distributed with mean $\omega^* + \lambda\phi(\theta)\frac{\varepsilon^*(\theta)}{2}$ and variance $[\varepsilon^*(\theta)]^2/a^{*2}$.

signed to offshored tasks is higher than ω^*. The compensation gap $E[w_i^*(\theta)] - \omega^*$ increases with task offshorability, captured by a higher level of $\lambda\phi(\theta)$, where $\overline{\theta} \leq \theta < 1$, and with task-specific effort $\varepsilon^*(\theta)$.

Our paper makes several contributions. The model predicts that workers assigned to offshored tasks in the South get higher compensation on average than other workers employed by domestic firms. This happens because workers are risk averse and must be compensated for the production uncertainty and effort in the modern sector. In other words, risk averse workers in the South with higher skill levels or education a^* exert greater effort and receive higher expected earnings. The model also demonstrates a previously unknown link between worker productivity in the South and offshoring costs: *ceteris paribus*, workers employed in tasks that are more readily offshorable exert higher levels of effort and get higher expected compensation. From the perspective of Northern firms, higher offshorability is equivalent to higher "productivity" of a worker assigned to an offshored task.

The model's predictions regarding the structure of wages in the South are consistent with empirical evidence. For example, Aitken, Hanson, and Harrison (1996) have documented that workers employed by multinational firms in the South on average get higher wages than workers employed by Southern domestic firms. Feenstra and Hanson (1997), among others, have documented that globalization has increased the skill premium among workers employed by foreign firms in the South. Our model suggests the following testable hypothesis. Part of the wage premium paid by foreign firms to their employees observed in the data could be explained by performance-pay contracts inducing higher worker effort.

Our model provides a new testable perspective on wage inequality in the South. It predicts that, regardless of the skill intensity of production, average compensation of workers employed in readily offshorable components or services must be higher than the average compensation of workers employed in less offshorable activities.

Antràs et al (2006) developed a model of offshoring which makes similar predictions about labor compensation in the South. Their model assumes skill differences among economic agents, and highlights the effects of globalization on matching between high-ability Northern managers and lower-ability Southern workers. Offshoring brings about better managers matched with better Southern workers, increasing the productivity and earnings of workers. In contrast, our model assumes that all workers in the South have the same observed skills.

In our model, the observed compensation structure depends on activity-specific offshorability costs that result in activity-specific effort. This aspect complements the Antràs et al (2006) model in at least two important ways. First, it highlights the role of incentive contracts and heterogeneous offshoring costs in bringing about inequality of compensation among Southern workers with the same skill. Our model generates "endogenous" heterogeneity in compensation. In contrast, Antràs et al (2006) focus on the effects of matching among workers with different skills generating "exogenous" heterogeneity in compensation among Southern workers.

The second difference between the two approaches is more salient. In our model, the participation constraint together with the assumption of perfect worker mobility (among tasks and production segments) imply equalization of expected utility among all workers. Heterogeneous earnings among workers come about because of incentive-based endogenous effort. As a result, low-wage earners are not worse off than high-wage earners. In contrast, in Antràs et al (2006), earnings heterogeneity is ultimately tied to exogenous skill distributions. Higher-skill workers and managers are better off because they receive greater compensation, without exerting greater effort. We conjecture that in reality both aspects of wage inequality coexist.

5 Labor Endowments and Offshoring

In our model, the fraction of offshored tasks and wage structure are endogenous and depend on virtually all parameters. We organize the presentation of comparative statics properties with ascending degree of complexity. This section addresses the impact of two dimensions of globalization stemming from changes in labor endowments. These changes leave worker effort unaffected and work primarily though changes in traditional wages: a size expansion of low-wage South measured by its labor force; and international labor migration from South to North. The next section addresses the effects of parameters affecting contract structure and worker effort: changes in worker skill, production uncertainty, and offshoring costs.

5.1 Larger South

The past few decades have witnessed the emergence of Brazil, Russia, India and China, the so called BRICs, as major global players. Roughly speaking, the emergence of BRICs amounts to more than doubling the supply of global labor in a relatively short period of time. China and India with a combined population of more than 2.5 billion have become popular offshoring destinations: factories in Guang-zhu and call centers in Bangalore have reinforced the perception that offshoring could become a serious threat to living standards of American and European workers independently of their skill level. Is this perception correct? Does an increase in the size of low-wage South augment the fraction of offshored tasks and increase the amount of offshored jobs? And if it does, are workers in the North or/and South better or worse off?

In our model, an increase in the labor force of the South n^* may be interpreted as the emergence of BRICs. The following proposition states the effects of an increase in South's size.

Proposition 2 *An increase in the Southern labor force has the following effects:*
(i) the fraction of offshored tasks $(1-\overline{\theta})$ *and the number of workers assigned to each task* n_m *increase;*
(ii) the number of offshored jobs $(1-\overline{\theta})n_m$ *and the number of Northern workers employed in the modern segment* $\overline{\theta}n_m$ *increase;*

(iii) Northern workers become better off because ω increases; and Southern workers become worse off because ω^* declines.

Proof. See Appendix. ■

A rise in the Southern labor force n^* does not affect the bonus offered by firms and worker effort. However, it increases the fraction of offshored tasks, $1 - \overline{\theta}$ and the employment per task, n_m. An increase in the size of the South n^* provides more offshored jobs, measured by $(1- \overline{\theta})n_m$, and *more* jobs in the modern sector in the North, measured by $\overline{\theta}n_m$. It also increases worker welfare in the North by increasing the traditional wage ω, and reduces worker welfare in the South by decreasing the traditional wage ω^*. As a result, this facet of globalization expands the North-South wage gap $\omega - \omega^*$ and worsens global wage inequality.

Figure 2 may illustrate these results geometrically. An increase in the labor force in the South shifts up only curve SS (not shown). As a result, point A moves left along curve NN yielding a greater fraction of offshored activities, a higher number of offshored jobs, and a larger North-South wage gap.

The economic intuition behind these results is as follows. An increase in the number of workers in the South works through the standard supply channel. An increase in Southern labor supply lowers the corresponding traditional wage and renders offshoring more profitable. As a result, Northern firms offshore more tasks and expand the number of workers assigned to each task. A larger fraction of offshored tasks implies that less productive tasks must be offshored. The minimum wage gap between offshored and traditional production segments in the South declines. The range of compensation across offshored tasks increases.

The assumption that an equal number of workers is assigned to each task implies that, although a smaller fraction of tasks remains in the North, each task is performed by a greater number of workers. The increase in the number of workers assigned to each task (intensive offshoring margin) dominates the reduction in the range of tasks performed in the North (extensive offshoring margin). As a result, the number of jobs in the Northern modern segment increases. Paradoxically, in this case, offshoring of tasks creates more jobs in the North! This finding stems from our assumption establishing complementarity across tasks within the supply chain. For example, if Ford expands output and creates more jobs in Mexico, where it assembles engines, it is very likely to observe an expansion in complementary U.S.-based operations such as R&D, marketing and distribution. The expansion in U.S.-based operations might (and within the context of our model does) generate more jobs in the U.S. despite the transfer of tasks to low-wage Mexico.

5.2 International Migration

According to Borjas (1999), by the end of the 20th century about 2 percent of world population resided in a country where they were not born. The percentage of foreign-born residents is much higher in Canada (17%), France (11%) and the U.S. (9%). The annual flow of U.S. immigrants is estimated between one and two million workers with the majority originating in Latin America (Mexico in particular) and Asia. International labor flows have generated intense policy debates regarding their effects on host-country workers, border security, and even the magnitude of offshoring.

In our model, the North-South wage gap, measured by $\omega - \omega^*$, creates incentives for workers to move from the low-wage South to the high-wage North. At first glance, offshoring and migration represent two sides of the same coin: under offshoring, foreign-born workers perform offshored tasks in the South; under migration, foreign-born workers could, in principle, perform the same tasks in the North. Surprisingly, migration and offshoring generate different effects on the structure of wages and worker welfare.

We begin the analysis of international migration by stating an obvious implication of Assumption 1: the North-South wage gap remains positive even if all activities are located in the North, that is, if no offshoring occurs. In other words, free international labor mobility leads to a corner solution without any offshoring. We therefore analyze a more realistic case: allowing an exogenous and small number of Southern workers $\mu > 0$ to migrate. This may be interpreted as the North adopting greater immigration quotas (say from 0 to μ).[37]

We focus on long-run effects of migration and, for simplicity, assume that the skill (educational) level of Southern immigrants equals that of Northern workers, that is, all workers residing in the North have skill level equal to a. Increasing immigration quotas by μ implies then that Northern labor force expands and Southern labor force contracts by μ.

A few comparative statics properties, including the effects of international migration on the number of workers assigned per task, are in general ambiguous because they depend on how offshoring impacts the labor demand in the traditional segment across the two regions. The following assumption offers a sufficient condition that removes this ambiguity.

Assumption 3: $\psi(\overline{\theta}) = \overline{\theta}\frac{\partial n_t^*}{\partial \omega^*} - (1-\overline{\theta})\frac{\partial n_t}{\partial \omega} < 0.$

Assumption 3 holds if the initial fraction of offshored tasks $1-\overline{\theta}$ is small. To see this property, observe that $\psi(0) = -\frac{\partial n_t}{\partial \omega} > 0, \psi(1) = \frac{\partial n_t^*}{\partial \omega^*} < 0$. [38]. Continuity of $\psi(\overline{\theta})$ implies that there exists a $\widehat{\theta}\,\epsilon[0,1]$ such that $\psi(\widehat{\theta}) = 0$ and $\psi(\overline{\theta}) < 0$ for $\overline{\theta}\epsilon(\,\widehat{\theta}, 1]$. In case of multiple solutions to $\psi(\widehat{\theta}) = 0$, consider the maximum solution for $\widehat{\theta}$. Therefore, Assumption 3 is satisfied for low initial levels of offshoring $1-\overline{\theta}$.[39] Under Assumption 3, a marginal increase in the fraction of tasks performed in the North $\overline{\theta}$ reduces global demand for labor in the traditional sector.

[37] International migration is constrained by several forces including immigration policies. For example, Clemens (2011) reports that according to the Gallup World Poll more than 40 percent of adults in the poorest quartile of countries would like to move permanently into another country. He also reports that the annual U.S. Diversity Visa Lottery had 13.6 million applications from developing countries for 50,000 visas to enter the U.S. permanently.

[38] Equations (31) and (32) imply that $\omega^*(\theta) > 0$ and $\omega(\theta) > 0$ for $\theta\epsilon[0,1]$. As a result, the assumption of a well-behaved production function describing the traditional technology means that $\frac{\partial n_t}{\partial \omega} < 0$ and $\frac{\partial n_t^*}{\partial \omega^*} < 0$ for $\theta\epsilon[0,1]$.

[39] Assumption 3 holds under reasonable parameter restrictions. For example, suppose that output in the traditional-segment is produced under perfect competition and Cobb-Douglas production functions $y = T^{(1-\zeta)}n_t^{\zeta}$ and $y^* = (T^*)^{(1-\zeta)}(n_t^*)^{\zeta}$, where T and T^* denote specific factors of production such as land, or the level of segment-specific knowledge. Assumption 3 is then satisfied under sufficient condition $1-\overline{\theta} \leq T^*/(T^*+T)$, requiring that the equilibrium fraction of offshored activities is sufficiently low. Specifically, Northern and Southern demands for labor are given by $n_t = \zeta T\omega^{(\zeta-1)}$and $n_t^* = \zeta T^*(\omega^*)^{(\zeta-1)}$, respectively. Differentiating these two expressions and using (33) and (34) yields $\frac{\partial n_t}{\partial \overline{\theta}} + \frac{\partial n_t^*}{\partial \overline{\theta}} = B\left[T(1-\overline{\theta})\omega^{(\zeta-2)} - T^*\overline{\theta}(\omega^*)^{(\zeta-2)}\right]$, where $B = \zeta(1-\zeta)\lambda\frac{\partial \phi}{\partial \overline{\theta}}(a^*+\varepsilon^*) > 0$. The term in square brackets is negative if and only if $\overline{\theta} > \widehat{\theta} = \left[1 + \frac{T^*}{T}\left(\frac{\omega}{\omega^*}\right)^{2-\zeta}\right]^{-1} < 1$. This condition holds as $\overline{\theta} \to 1$, that is for a small initial fraction of offshored tasks.

To see this property add equations (35) and (36) to obtain the global labor market condition $n + n^* = n_m + n_t[\omega(\theta)] + n_t^*[\omega^*(\theta)]$. Differentiate the global full employment condition and substitute (33) and (34) to obtain $\frac{\partial n_m}{\partial \theta} = -\lambda \frac{\partial \phi}{\partial \theta}(a^* + \varepsilon^*)\psi(\overline{\theta}) > 0$. For expositional purposes, the description of propositions in the main text of the paper will focus on low initial levels of offshoring such that $\overline{\theta}\epsilon(\widehat{\theta}, 1]$.

The following proposition summarizes the effects of international migration from South to North.

Proposition 3 *An increase in the number of migrant workers moving from South to North has the following effects:*

(i) the fraction of offshored activities $1 - \overline{\theta}$ *declines;*

(ii) the number of workers employed in each activity n_m *increases;*

(iii) there is an ambiguous effect on the number of offshored jobs $(1 - \overline{\theta})n_m$*;*

(iv) the number of workers assigned to tasks in the North $\overline{\theta}n_m$ *expands;*

(v) Northern workers become worse off because ω *decreases;*

(vi) Southern workers left behind become better off because ω^* *increases;*

(vii) Southern immigrants become better off because they receive a higher wage $\omega > \omega^*$*.*

Proof. See Appendix . ■

The economic intuition behind these results is as follows. As in the case of a larger South, international migration does not affect the level of worker effort and labor productivity. It works through its impact on wages, reducing the traditional wage in the North (as the supply of labor expands) and increasing the traditional wage in the South (as the supply of labor contracts). The reduction in the North-South wage gap makes offshoring less profitable reducing its extensive margin as firms keep more tasks in the North. For low initial levels of offshoring, Assumption 3 ensures that the intensive margin of offshoring n_m increases as more workers move from the traditional to the modern segment of production in the South. A lower fraction of offshored activities and more workers assigned in each task mean that the number of jobs in the Northern modern sector expands and employment in the offshored segment of production may rise of fall. The effects of greater immigration quotas on Northern workers, Southern workers and Southern immigrant workers follow directly from the migration effects on wages.

The model's predictions on the effects of international migration on wages are consistent with the empirical literature. For example, Borjas (2003) reports that immigration has reduced the average U.S. wage by about 3 percent and wages of high school dropouts by about 20 percent.

6 Effort and Offshoring

Performance-pay contracts induce workers to exert effort under conditions of uncertainty and moral hazard. In the present model, when firms offer higher bonuses they generate more worker effort. As a result, performance-pay contracts provide a novel mechanism that links several novel structural parameters with the equilibrium level of worker effort, labor productivity, offshoring patterns, wages, and worker welfare. Parameters that affect worker productivity through unobserved effort include the level of worker skill, the degree of production (or performance monitoring) uncertainty, and the level of offshoring costs.

Equation (12) indicates that the equilibrium level of effort per task in the North increases in the level of worker skill a and declines in the degree of production and/or monitoring uncertainty σ^2. Similarly, equation (25) indicates that the equilibrium level of effort per task in the South increases in the level of worker skill a^* and the reduction in offshoring costs captured by λ; and declines in the degree of production uncertainty σ^{*2}.[40]

An increase in the size of the South, or greater immigration quotas, works primarily through the resource reallocation mechanism leaving intact the equilibrium levels of bonus and effort in each region. In contrast, changes in parameters governing the structure of

[40] Worker effort declines in the degree of absolute risk aversion r. The effects of this parameter are similar to those of σ^{*2} and are briefly discussed at the end of this section.

performance-pay contracts operate through worker effort reflected in the equilibrium level of worker productivity. This section provides a general equilibrium analysis of parameters that affect worker effort. Such analysis is missing from the existing literature.

We start the discussion by considering an increase in Northern worker effort caused by a higher level of worker skill a or a lower degree of production (monitoring) uncertainty σ^2. Equation (32) implies that either change leads to a higher bonus, effort and labor productivity, and therefore raises the traditional wage in the North, that is, $\partial\omega/\partial a > 0$, $\partial\omega/\partial\sigma^2 < 0$. Equation (31) implies that the traditional wage in the South does not depend on these parameters, that is, $\partial\omega^*/\partial a = 0$, $\partial\omega^*/\partial\sigma^2 = 0$.

An increase in Northern labor productivity induced by greater effort raises task profitability in the North and reduces the fraction of offshored tasks $1 - \overline{\theta}$ according to (29). A lower fraction of offshored tasks requires a higher traditional wage in the South according to (33) because $\partial\omega^*/\partial\overline{\theta} > 0$. Interestingly, offshoring creates a novel channel that transmits the beneficial "productivity" effect from North to South resulting in higher traditional wages in both regions. Higher wages eliminate short-run profits created by higher worker effort in the North. Faced with higher traditional wages, workers move from from the traditional to the modern segment in each region resulting in a higher number of workers assigned to each task n_m. Therefore, the number of workers employed in the modern Northern segment increases; and, surprisingly, the number of Southern workers employed in offshored tasks increases as well. As it turns out, the rise in the number of workers per task dominates the decline in the fraction of offshored tasks leading to modern-segment job creation in both regions! The following proposition summarizes these novel findings.

Proposition 4 *An increase in Northern worker bonus and effort caused by a rise in worker skill a or a decline in the degree of production uncertainty σ^2, leads to the following effects:*
(i) the fraction of offshored activities $1 - \overline{\theta}$ declines;
(ii) the number of workers employed in each activity n_m expands;
(iii) the number of offshored jobs $(1 - \overline{\theta})n_m$ and the number of jobs in the Northern modern

segment $\overline{\theta}n_m$ increase;

(iv) Northern workers become better off, because ω increases;

(v) Southern workers become better off because ω^* increases.

Proof. See Appendix . ■

Consider next the general equilibrium effects of higher worker effort per task in the South caused by either higher level of worker skill a^*, lower degree of production uncertainty σ^{*2}, or lower offshoring costs measured by an increase in λ.

The relationship between a rise in λ and reduction in trade costs needs clarification. In the context of our model, technological advances can be analyzed by considering an increase in parameter λ. A higher value of λ implies that a larger fraction of each offshored unit of output can be used productively in the North. Accordingly, an increase in λ may be interpreted as a reduction in offshoring (or trade) costs.

Equations (32) and (31) reveal that each of these parameter changes increases traditional wages in both North and South, that is, $\partial\omega/\partial a^* > 0, \partial\omega^*/\partial a^* > 0$, $\partial\omega/\partial\sigma^{*2} < 0$ and $\partial\omega^*/\partial\sigma^{*2} < 0$. In general, the effects of higher worker effort in the South are similar to the effects of an increase in worker effort in the North. The rise in worker effort in the South leads to more profitable offshoring and raises the fraction of offshored tasks $1-\overline{\theta}$. In the long-run, free entry leads to zero profits requiring higher wages in the North. Accordingly, higher effort of Southern workers translates into higher traditional wages in both regions. The latter induce firms in the traditional segment to reduce employment and thus generate a flow of workers from the traditional to the modern segment in each region. This labor reallocation generates a higher number of workers assigned to each task n_m, and implies more offshored jobs and more jobs in the modern segment in the North, that is, the increase in n_m dominates the change in $\overline{\theta}$. These findings are summarized in the following proposition.

Proposition 5 *An increase in Southern worker bonus and effort caused by lower offshoring costs λ, a rise in worker skill a^* or by a decline in the degree of uncertainty σ^{*2}, has the* *following effects:*

(i) the fraction of offshored activities $1 - \overline{\theta}$ *increases;*

(ii) the number of workers employed in each activity n_m *expands;*

(iii) the number of offshored jobs $(1 - \overline{\theta})n_m$ *and the number of jobs in the Northern modern segment* $\overline{\theta}n_m$ *increase;*

(iv) Northern workers become better off because ω *increases;*

(v) Southern workers become better off because ω^* *increases.*

Proof. See Appendix . ■

The literature on offshoring highlights the role of advances in transportation and communication technologies which have substantially reduced offshoring costs. Proposition 5 complements the existing literature by incorporating the analysis of lower offshoring costs in an environment where worker effort is governed by performance-pay contracts and labor productivity depends on worker effort. In our model, lower offshoring costs increase intensive and extensive offshoring margins, provide higher employment in the modern sector in each region, and make workers better off in both North and South.

The rationale behind the beneficial effects of lower offshoring costs is related to the novel *effort-based* productivity effect and the standard *task–selection* productivity effect. Specifically, a reduction in offshoring costs increases the productivity of workers assigned to offshored tasks through two distinct channels. First, lower offshoring costs raise effective output per offshored task for any given effort level. A larger fraction of output per task "arrives" to the North. This channel has been highlighted and analyzed by Grossman and Rossi-Hansberg (2008) in the context of the Heckscher-Ohlin trade model and the assumption of perfectly competitive labor markets. This is the task-selection productivity effect because across the board lower offshoring costs lead to lower average and marginal costs in the North. Second, smaller offshoring costs induce more worker effort in the South and increase further labor productivity in offshored tasks. Our paper is the first to identify this effort-based productivity effect. Both channels work in the same direction inducing higher labor productivity and profitability of offshored tasks.

An expansion in offshored tasks creates a reallocation of labor in the South. Workers move from the traditional to the offshored production segment. This labor movement is achieved through a rise in the traditional wage that reduces the amount of labor demanded in the traditional segment. Reallocation of labor from low to higher productivity segments benefits workers in the South by increasing their compensation. In the North, excess profits in offshored tasks are eliminated through a rise in worker compensation. Thus, traditional wages and worker welfare increase in both North and South, thanks to the enhanced productivity of offshored tasks caused by lower offshoring costs and greater worker effort.

Proposition 5 states that the effects of lower output uncertainty or higher skill in the South have the same beneficial effects as lower offshoring costs: they induce more effort in the South, increase worker labor productivity, and make workers in both regions better off. These parameters are measurable: output uncertainty is observable, and worker skill is correlated to measures of human capital. As a result, Propositions 5 and 4 offer testable hypotheses to empirical researchers interested in the determinants of offshoring.

Finally, for completeness, we offer a few remarks regarding the impact of the coefficient of risk aversion r. This is not a policy-related parameter and, as a result, brief exposition is sufficient. A reduction in r induces firms in both regions to offer higher incentives to workers through larger bonuses. As a result, worker effort and labor productivity increase in both regions. Accordingly, it is straightforward to establish that, under Assumptions 1, 2 and 3, the effects of a lower absolute risk aversion are identical to the effects of higher worker effort in the South as described by Proposition 5.

7 Concluding Remarks

We analyzed formally the effects of offshoring by incorporating performance-pay, piece-rate, contracts in a general equilibrium model of offshoring between a high-wage North and a low-wage South. The benchmark model provides a tractable general equilibrium framework to analyze endogenous interactions among moral hazard and effort, firm size, and worker opportunity costs. These interactions have been absent from the literature on performance-pay contracts that uses partial-equilibrium techniques and typically assumes exogenous reservation utility. We modeled offshoring as an international transfer of managerial practices and production techniques that involve implementation and monitoring of performance-pay contracts offered to workers who are assigned to offshored tasks. Heterogeneous offshoring costs and endogenous unobserved effort enhance the productivity effect of offshoring and amplify the wage-income inequality in the South.

The debate on offshoring is primarily about jobs and wages. Since offshoring is a global phenomenon, we also addressed the effects of globalization on jobs and wages in the North. We find that where globalization increases the fraction of offshored tasks, as in the case of a larger South or lower offshoring costs, it increases the productivity of workers assigned to offshored tasks and benefits Northern workers. In contrast, where globalization shrinks the fraction of offshored tasks, as in the case of migration from South to North, it hurts Northern workers by reducing their earnings. An increase in the size of the South hurts Southern workers by reducing their expected compensation. In contrast, a reduction in offshoring costs or international migration from South to North benefits Southern workers.

We also analyzed the effects of parameters that govern worker effort in each region by changing the structure of perfomance-pay contracts. An increase in worker skill or a reduction in production uncertainty induce firms to offer higher bonuses and lead to a higher worker effort and productivity. Higher worker effort in either region has the same impact as lower offshoring costs: it creates more jobs in the modern segment of production in the North and more employment in the offshored segment in the South; it also benefits Northern and Southern workers by increasing their expected earnings. The effects of parameters that govern the power of performance-pay contracts are missing from the literature on offshoring. Our paper fills this gap in the literature.

The analysis offers several testable implications. For example, part of the wage premium paid by foreign firms to their employees observed in the data could be explained by performance pay contracts inducing higher worker effort and wages. In addition, empirical studies analyzing the determinants of offshoring patterns and wages, in environments where performance pay contracts are prevalent, could include production uncertainty proxied by the variance of industry-specific output, and measures of worker skill such as level of education in accordance to Propositions 4 and 5.

The model can be extended in several directions. Relative performance or hybrid and non-linear contracts could be readily introduced in the analysis to address the robustness of the main results. The assumption that the level of skill (or ability) is observable and equal across all workers within each region could also be relaxed increasing the model's empirical relevance. The absence of substitution of workers across tasks is also restrictive and could be replaced. Introducing heterogeneous production uncertainty across tasks, measured by task variance, might lead to the prediction that tasks with lower production uncertainty would be more likely to be offshored. Finally, expanding on contractual enforcement issues under different institutional settings could lead to the study of the appropriate vertical integration structure, that is, the make or buy decision, within a general equilibrium context. These issues are beyond the scope of this paper and constitute fruitful avenues for future research.

8 Appendix

Comparative statics are governed by a system of four equations (31), (32), (35) and (36). The first two determine traditional wages in South ω^* and North ω as functions of the fraction of tasks performed in the North $\overline{\theta}$ and parameters; and the last two equations are full-employment conditions of labor and determine the fraction of tasks performed $\overline{\theta}$ and the number of workers assigned in each task n_m. We reproduce these equations below for reference purposes.

$$\omega^*(\overline{\theta}) = \overline{\theta}\left[\lambda\phi(\overline{\theta})a^* + \frac{\lambda\phi(\overline{\theta})\varepsilon^*(\overline{\theta})}{2}\right] + \int_{\overline{\theta}}^{1}\left[\lambda\phi(\theta)a^* + \frac{\lambda\phi(\theta)\varepsilon^*(\theta)}{2}\right]d\theta, \tag{39}$$

$$\omega(\overline{\theta}) = \left(a + \frac{\varepsilon}{2}\right) + \int_{\overline{\theta}}^{1}\lambda a^*[\phi(\theta) - \phi(\overline{\theta})]d\theta + \frac{\lambda}{2}\int_{\overline{\theta}}^{1}\left[\phi(\theta)\varepsilon^*(\theta) - \phi(\overline{\theta})\varepsilon^*(\overline{\theta})\right]d\theta, \tag{40}$$

where the relationship $(1-\overline{\theta})\left[\lambda\phi(\overline{\theta})a^* + \frac{\lambda\phi(\overline{\theta})\varepsilon^*(\overline{\theta})}{2}\right] = \int_{\overline{\theta}}^{1}\left[\lambda\phi(\overline{\theta})a^* + \frac{\lambda\phi(\overline{\theta})\varepsilon^*(\overline{\theta})}{2}\right]d\theta$ has been incorporated in equation (40). The two full-employment of labor conditions are

$$n = \overline{\theta}n_m + n_t[\omega(\overline{\theta})], \tag{41}$$

$$n^* = (1-\overline{\theta})n_m + n_t^*[(\omega^*(\overline{\theta})]. \tag{42}$$

8.1 Proof of Proposition 2

The effects of an increase in Southern labor force n^* can be obtained by totally differentiating the full-employment conditions (41) and (42), respectively, yielding

$$\frac{d\overline{\theta}}{dn^*} = -\frac{\overline{\theta}}{D} < 0;\ \frac{dn_m}{dn^*} = \frac{n_m + \frac{\partial n_t}{\partial\overline{\theta}}}{D} > 0, \tag{43}$$

where

$$D = (1-\overline{\theta})(n_m + \frac{\partial n_t}{\partial\overline{\theta}}) + \overline{\theta}(n_m - \frac{\partial n_t^*}{\partial\overline{\theta}}) > 0, \tag{44}$$

since

$$\frac{\partial n_t}{\partial\omega} < 0;\frac{\partial n_t^*}{\partial\omega^*} < 0;\ \frac{\partial\omega^*}{\partial\overline{\theta}} > 0;\ \frac{\partial\omega}{\partial\overline{\theta}} < 0;\ \frac{\partial n_t}{\partial\overline{\theta}} = \frac{\partial n_t}{\partial\omega}\frac{\partial\omega}{\partial\overline{\theta}} > 0;\ \frac{\partial n_t^*}{\partial\overline{\theta}} = \frac{\partial n_t^*}{\partial\omega^*}\frac{\partial\omega^*}{\partial\overline{\theta}} < 0. \tag{45}$$

Inequalities stated in (45) require a brief explanation. The first two state that the demand for labor employed in the traditional sector in each region declines in the traditional wage. The next two are derived by partially differentiating equations (39) and (40) as indicated by equations (33) and (34) in the main text. The last two follow directly from the previous four inequalities in (45).

According to (43), a marginal increase in the Southern labor force increases the fraction of offshored tasks $1-\overline{\theta}$ and the number of workers assigned in each task n_m. This establishes part (i) of Proposition 2 implying that employment in offshored activities $(1-\overline{\theta})n_m$ expands. The expansion in workers assigned in each task dominates the reduction in the fraction of tasks remaining in the North. This leads to an increase in Northern modern-segment employment $\overline{\theta}n_m$. Formally, totally differentiating $\overline{\theta}n_m$, substituting (43), and using (44) and (45) yields

$$\frac{d(\overline{\theta}n_m)}{dn^*} = \overline{\theta}\frac{dn_m}{dn^*} + n_m\frac{d\overline{\theta}}{dn^*} = \frac{\overline{\theta}\frac{\partial n_t}{\partial \overline{\theta}}}{D} > 0 \tag{46}$$

and proves part (ii) of Proposition 2. Finally, the effect of an increase in n^* on traditional wages $\omega(\overline{\theta})$ and $\omega^*(\overline{\theta})$ is obtained as follows

$$\frac{d\omega}{dn^*} = \frac{\partial\omega}{\partial\overline{\theta}}\frac{d\overline{\theta}}{dn^*} > 0; \;\; \frac{d\omega^*}{dn^*} = \frac{\partial\omega^*}{\partial\overline{\theta}}\frac{d\overline{\theta}}{dn^*} > 0, \tag{47}$$

based on (43) and (45). This establishes part (iii) of Proposition 2 and completes its proof.

8.2 Proof of Proposition 3

Substitute $n+\mu$ and $n^*-\mu$ in the left-hand-side of full-employment conditions in the North and South, (41) and (42), respectively. Differentiating the resulting system of equations and using Cramer's rule provides

$$\frac{d\overline{\theta}}{d\mu} = \frac{1}{D} > 0, \tag{48}$$

$$\frac{dn_m}{d\mu} = \frac{\frac{\partial n_m}{\partial \theta}}{D} - \frac{\lambda\frac{\partial \phi}{\partial \theta}(a^*+\varepsilon^*)\psi(\overline{\theta})}{D} > 0, \tag{49}$$

where $D > 0$, based on (44), and $\psi(\overline{\theta}) < 0$ based on Assumption 3. Part (i) of Proposition 3 follows directly from (48). Parts (ii), (iii) and (iv) follow from (48) and (49).

The effect of a marginal increase in μ on traditional wages $\omega(\overline{\theta})$ and $\omega^*(\overline{\theta})$ is given by

$$\frac{d\omega}{d\mu} = \frac{\partial\omega}{\partial\overline{\theta}}\frac{d\overline{\theta}}{d\mu} = \frac{\partial\omega}{\partial\overline{\theta}}\frac{1}{D} < 0; \; \frac{d\omega^*}{d\mu} = \frac{\partial\omega^*}{\partial\overline{\theta}}\frac{d\overline{\theta}}{d\mu} = \frac{\partial\omega^*}{\partial\overline{\theta}}\frac{1}{D} > 0, \tag{50}$$

based on (45) and (48). As a result, inequalities (50) establish parts (v) and (vi) of Proposition 3. Part (vii) follows directly from the existence of a positive North-South wage gap, that is, $\omega > \omega^*$. Greater immigration quotas reduce but do not eliminate the North-South wage gap. This concludes the proof of Proposition 3.

8.3 Proof of Proposition 4

Equation (12) implies $\frac{\partial\varepsilon}{\partial a} = \frac{a(a+2r\sigma^2)}{(a+2r\sigma^2)^2} > 0$ and $\frac{\partial\varepsilon}{\partial\sigma^2} = -\frac{1}{2}\frac{a^2}{(a+2r\sigma^2)^2} < 0$; and equation (32) implies that $\frac{\partial w}{\partial a} = 1 + \frac{1}{2}\frac{\partial\varepsilon}{\partial a} > 0$ and $\frac{\partial w}{\partial\sigma^2} = \frac{1}{2}\frac{\partial\varepsilon}{\partial\sigma^2} < 0$. In words, an increase in worker skill in the North or a decline in production uncertainty raise directly the level of worker effort and traditional wage in the North. Equations (25) and (31) imply that the levels of Southern effort and traditional wage are independent of these parameters, that is, $\frac{\partial\varepsilon^*}{\partial a} = \frac{\partial\varepsilon^*}{\partial\sigma^2} = \frac{\partial\omega^*}{\partial a} = \frac{\partial\omega^*}{\partial\sigma^2} = 0$.

For brevity of exposition, define parameter $\chi\epsilon\{a, -\sigma^2\}$ such that an increase in χ corresponds to an increase in a or a decline in σ^2. Accordingly, the above results can be summarized as

$$\frac{\partial\varepsilon}{\partial\chi} > 0, \; \frac{\partial w}{\partial\chi} > 0, \; \frac{\partial\varepsilon^*}{\partial x} = \frac{\partial w^*}{\partial x} = 0. \tag{51}$$

Totally differentiating Northern and Southern full-employment conditions (41) and (42), recognizing the dependence of each wage on χ, and using Cramer's rule yield

$$\frac{d\overline{\theta}}{d\chi} = -\frac{(1-\overline{\theta})}{D}\frac{\partial n_t}{\partial w}\frac{\partial w}{\partial\chi} > 0, \tag{52}$$

$$\frac{dn_m}{d\chi} = \frac{1}{D}(\frac{\partial n_t^*}{\partial \overline{\theta}} - n_m)\frac{\partial n_t}{\partial w}\frac{\partial w}{\partial \chi} > 0, \tag{53}$$

where $D > 0$ is defined in (44); $\frac{\partial n_t^*}{\partial \theta} - n_m < 0$, $\frac{\partial n_t}{\partial w} < 0$; and $\frac{\partial w}{\partial \chi} > 0$ in accordance to (51).

Equations (52) and (53) establish parts (i) and (ii) of Proposition 4: an increase in effort caused by higher worker skill a or lower production uncertainty σ^2 in the North reduces the fraction of offshored activities $1 - \overline{\theta}$ and increases the number of workers assigned in each activity n_m. These equations imply that the number of jobs in the Northern modern segment $\overline{\theta} n_m$ increases.

At first glance, a marginal increase in χ has an ambiguous impact on offshored employment $(1 - \overline{\theta})n_m$ because it decreases the "extensive" job margin $(1 - \overline{\theta})$ and increases the "intensive" job margin n_m. However, it can be shown that the second effect dominates the first resulting in higher offshored employment. Differentiating expression $(1 - \overline{\theta})n_m$ with respect to χ and substituting (52) and (53) yields

$$\frac{d[(1-\overline{\theta})n_m]}{d\chi} = (1-\overline{\theta})\frac{dn_m}{d\chi^*} - n_m\frac{d\overline{\theta}}{d\chi^*} = \frac{(1-\overline{\theta})}{D}\frac{\partial n_t^*}{\partial \overline{\theta}}\frac{\partial n_t}{\partial w}\frac{\partial w}{\partial \chi} > 0, \tag{54}$$

where $\frac{\partial n_t^*}{\partial \theta} < 0$, $\frac{\partial n_t}{\partial w} < 0$, and $\frac{\partial w}{\partial \chi} > 0$. As a result, an increase in Northern effort caused by higher ability or lower production uncertainty increases employment in the modern sector in both North and South establishing part (iii) of Proposition 4.

To prove part (iv) of Proposition 4 differentiate the Northern wage $w(\overline{\theta})$ with respect to χ recognizing the dependence of θ on χ , and using (52) ,to obtain

$$\frac{dw}{d\chi} = \frac{\partial w}{\partial \overline{\theta}}\frac{d\overline{\theta}}{d\chi} + \frac{\partial w}{\partial \chi} = \left[1 - \frac{(1-\overline{\theta})\frac{\partial n_t}{\partial \overline{\theta}}}{n_m + (1-\overline{\theta})\frac{\partial n_t}{\partial \overline{\theta}} - \frac{\partial n_t^*}{\partial \overline{\theta}}}\right]\frac{\partial w}{\partial \chi} > 0. \tag{55}$$

Finally, part (v) of Proposition 4 is established by differentiating Southern wage $w^*(\overline{\theta})$ with respect to χ and recognizing that $\frac{\partial w^*}{\partial x} = 0$ from (51), to obtain $\frac{dw^*}{d\chi} = \frac{\partial w^*}{\partial \overline{\theta}}\frac{d\overline{\theta}}{d\chi} > 0$. As a result, an increase in Northern effort raises the traditional wage in the South $w^*(\overline{\theta})$ and increases the welfare of Southern workers. This completes the proof of Proposition 4.

8.4 Proof of Proposition 5

Equation (25) implies $\frac{\partial\varepsilon^*}{\partial a^*} = \frac{\lambda\phi(\theta)a^*(a^*+2r\sigma^{*2})}{(a^*+2r\sigma^{*2})^2} > 0$, $\frac{\partial\varepsilon^*}{\partial\sigma^{*2}} = -\frac{1}{2}\frac{\lambda\phi(\theta)a^{*2}}{(a^*+2r\sigma^{*2})^2} < 0$ and $\frac{\partial\varepsilon^*}{\partial\lambda} = \frac{\phi(\theta)a^{*2}}{(a^*+2r\sigma^{*2})^2} > 0$: an increase in worker skill in the South, a reduction in production uncertainty or a reduction in offshoring costs increase the equilibrium level of worker effort per task. Equation (12) implies worker effort in the North is not affected by changes in these parameters, that is, $\frac{\partial\varepsilon}{\partial a^*} = \frac{\partial\varepsilon}{\partial\sigma^{*2}} = \frac{\partial\varepsilon}{\partial\lambda} = 0$.

The next step consists of calculating the effects of the aforementioned parameter on traditional wages in the North and South for a given $\overline{\theta}$. Partial differentiating of equation (39) with respect to parameters of interest yields

$$\frac{\partial\omega^*(\overline{\theta})}{\partial a^*} = \overline{\theta}\left[\lambda\phi(\overline{\theta}) + \frac{\lambda\phi(\overline{\theta})}{2}\frac{\partial\varepsilon^*(\overline{\theta})}{\partial a^*}\right] + \int_{\overline{\theta}}^{1}\left[\lambda\phi(\theta) + \frac{\lambda\phi(\theta)}{2}\frac{\partial\varepsilon^*(\overline{\theta})}{\partial a^*}\right]d\theta > 0,$$

$$\frac{\partial\omega^*(\overline{\theta})}{\partial\sigma^{*2}} = \overline{\theta}\left[\frac{\lambda\phi(\overline{\theta})}{2}\frac{\partial\varepsilon^*(\overline{\theta})}{\partial\sigma^{*2}}\right] + \int_{\overline{\theta}}^{1}\left[\frac{\lambda\phi(\theta)}{2}\frac{\partial\varepsilon^*(\overline{\theta})}{\partial\sigma^{*2}}\right]d\theta < 0,$$

$$\begin{aligned}\frac{\partial\omega^*(\overline{\theta})}{\partial\lambda} &= \overline{\theta}\left[a^*\phi(\overline{\theta}) + \frac{\lambda\phi(\overline{\theta})}{2}\frac{\partial\varepsilon^*(\overline{\theta})}{\partial\lambda} + \frac{\phi(\overline{\theta})\varepsilon^*(\overline{\theta})}{2}\right] \\ &+ \int_{\overline{\theta}}^{1}\left[a^*\phi(\theta) + \frac{\lambda\phi(\theta)}{2}\frac{\partial\varepsilon^*(\theta)}{\partial\lambda} + \frac{\phi(\theta)\varepsilon^*(\theta)}{2}\right]d\theta > 0.\end{aligned}$$

The effects on the traditional wage in the North for any given $\overline{\theta}$ are calculated by differentiating (40) with respect to parameters of interest yielding

$$\frac{\partial\omega(\overline{\theta})}{\partial a^*} = \int_{\overline{\theta}}^{1}\lambda[\phi(\theta) - \phi(\overline{\theta})]d\theta + \frac{\lambda}{2}\int_{\overline{\theta}}^{1}\left[\phi(\theta)\frac{\partial\varepsilon^*(\theta)}{\partial a^*} - \phi(\overline{\theta})\frac{\partial\varepsilon^*(\overline{\theta})}{\partial a^*}\right]d\theta > 0,$$

$$\frac{\partial\omega(\overline{\theta})}{\partial\sigma^{*2}} = \frac{\lambda}{2}\int_{\overline{\theta}}^{1}\left[\phi(\theta)\frac{\partial\varepsilon^*(\theta)}{\partial a^*} - \phi(\overline{\theta})\frac{\partial\varepsilon^*(\overline{\theta})}{\partial a^*}\right]d\theta = -\frac{\lambda^2 a^{*2}}{4(a^* + 2r\sigma^{*2})^2}\int_{\overline{\theta}}^{1}\left[\phi(\theta)^2 - \phi(\overline{\theta})^2\right]d\theta < 0,$$

$$\frac{\partial \omega(\overline{\theta})}{\partial \lambda} = \int_{\overline{\theta}}^{1} a^*[\phi(\theta) - \phi(\overline{\theta})]d\theta + \frac{1}{2}\int_{\overline{\theta}}^{1} \left[\phi(\theta)\varepsilon^*(\theta) - \phi(\overline{\theta})\varepsilon^*(\overline{\theta})\right] d\theta + \\ + \frac{\lambda^2 a^{*2}}{2(a^* + 2r\sigma^{*2})^2} \int_{\overline{\theta}}^{1} \left[\phi(\theta)^2 - \phi(\overline{\theta})^2\right] d\theta.$$

Note that all definite integrals appearing in the previous three equations are strictly positive. An increase in worker effort in the South caused by an increase in worker skill, a reduction in uncertainty or a decline in offshoring costs raises the traditional wage in the South and North. The direct beneficial affect of higher Southern effort on Northern traditional wages is tied to the presence of offshoring.

For notational purposes, define parameter $\chi^* \epsilon \{a^*, -\sigma^{*2}, \lambda\}$ such that an increase in χ^* corresponds to higher Southern worker effort caused by an increase in worker skill a^*, a decline in production uncertainty σ^{*2}, or a reduction in offshoring costs captured by an increase in λ. We can then summarize the aforementioned results as

$$\frac{\partial \varepsilon}{\partial \chi^*} = 0,\ \frac{\partial w}{\partial \chi^*} > 0,\ \frac{\partial \varepsilon^*}{\partial x^*} > 0,\ \frac{\partial w^*}{\partial x^*} > 0. \tag{56}$$

In addition, observe that the first-order condition for profit maximization (29) implies that

$$\frac{\partial w^*}{\partial \chi^*} = C(\chi^*) + \frac{\partial w}{\partial \chi^*}, \tag{57}$$

where $C(\chi^*) = \frac{\partial}{\partial \chi^*}\left[\lambda\phi(\overline{\theta})a^* + \frac{\lambda\phi(\overline{\theta})\varepsilon^*(\overline{\theta})}{2}\right] > 0$. In other words, an increase in χ^* raises the traditional wage (in absolute value) in the South more than the traditional wage (in absolute value) in the North and leads to a reduction in the North-South wage gap.

Totally differentiating Northern and Southern full-employment conditions (41) and (42), recognizing the dependence of each wage on χ^*, and using Cramer's rule yield

$$\begin{aligned}
\frac{d\overline{\theta}}{d\chi^*} &= -\frac{1}{D}\left[(1-\overline{\theta})\frac{\partial n_t}{\partial w}\frac{\partial w}{\partial \chi^*} - \overline{\theta}\frac{\partial n_t^*}{\partial w^*}\frac{\partial w^*}{\partial \chi^*}\right] = && (58)\\
&= \frac{1}{D}\left[\left(\overline{\theta}\frac{\partial n_t^*}{\partial w^*} - (1-\overline{\theta})\frac{\partial n_t}{\partial w}\right)\frac{\partial w}{\partial \chi^*} + \overline{\theta}\frac{\partial n_t^*}{\partial w^*}C(\chi^*)\right] = && (59)\\
&= \frac{1}{D}\left[\frac{\partial w}{\partial \chi^*}\psi(\overline{\theta}) + \overline{\theta}\frac{\partial n_t^*}{\partial w^*}C(\chi^*)\right] < 0, && (60)
\end{aligned}$$

$$\frac{dn_m}{d\chi^*} = \frac{1}{D}\left[\left(\frac{\partial n_t^*}{\partial \overline{\theta}} - n_m\right)\frac{\partial n_t}{\partial w}\frac{\partial w}{\partial \chi^*} - \left(n_m + \frac{\partial n_t}{\partial \overline{\theta}}\right)\frac{\partial n_t^*}{\partial w^*}\frac{\partial w^*}{\partial \chi^*}\right] > 0, \tag{61}$$

where $D > 0$ is defined in (44); $\frac{\partial n_t^*}{\partial \overline{\theta}} < 0$, $\frac{\partial n_t}{\partial w} < 0$, and $\frac{\partial n_t}{\partial \overline{\theta}} > 0$ in accordance to (45); $\frac{\partial w}{\partial \chi^*} > 0$, $\frac{\partial w^*}{\partial \chi^*} > 0$ based on (56); and $\psi(\overline{\theta}) < 0$ in accordance to Assumption 3. Part (i) of Proposition 5 is established by (58): an increase in χ^* increases the fraction of offshored activities $1-\overline{\theta}$ starting at an initial low fraction of offshoring. Part (ii) of Proposition 5 follows directly from (61) stating that an increase in χ^* raises the number of workers assigned in each task.

The effects of χ^* on jobs are given by

$$\frac{d[\overline{\theta}n_m]}{d\chi^*} = \overline{\theta}\frac{dn_m}{d\chi^*} + n_m\frac{d\overline{\theta}}{d\chi^*} = \frac{1}{D}\left[\left(\overline{\theta}\frac{\partial n_t^*}{\partial \overline{\theta}} - n_m\right)\frac{\partial n_t}{\partial w}\frac{\partial w}{\partial \chi^*} - \overline{\theta}\frac{\partial n_t}{\partial \overline{\theta}}\frac{\partial n_t^*}{\partial w^*}\frac{\partial w^*}{\partial \chi^*}\right] > 0, \tag{62}$$

$$\begin{aligned}
\frac{d[(1-\overline{\theta})n_m]}{d\chi^*} &= (1-\overline{\theta})\frac{dn_m}{d\chi^*} - n_m\frac{d\overline{\theta}}{d\chi^*} = && (63)\\
&= \frac{1}{D}\left[\begin{array}{c} (1-\overline{\theta})\frac{\partial n_t^*}{\partial \overline{\theta}}\frac{\partial n_t}{\partial w}\frac{\partial w}{\partial \chi^*} - \\ -\left(\overline{\theta}n_m + (1-\overline{\theta})\left(n_m + \frac{\partial n_t}{\partial \overline{\theta}}\right)\frac{\partial n_t^*}{\partial w^*}\frac{\partial w^*}{\partial \chi^*}\right) \end{array}\right] > 0, && (64)
\end{aligned}$$

where $D > 0$ is defined in (44); $\frac{\partial n_t^*}{\partial \overline{\theta}} < 0$, $\frac{\partial n_t}{\partial w} < 0$, $\frac{\partial n_t^*}{\partial w^*} < 0$ and $\frac{\partial n_t}{\partial \overline{\theta}} > 0$ in accordance with (45); $\frac{\partial w}{\partial \chi^*} > 0$, $\frac{\partial w^*}{\partial \chi^*} > 0$ based on (56); Part (iii) of Proposition 5 is established by (62) and (63). Accordingly, an increase in effort in the South raises modern sector jobs in both regions. The effects of effort on jobs depend on its impact on the intensive margin n_m and not so much on the extensive margin θ. As a result, part (iii) of Proposition 5 does not rely on Assumption 3.

Finally, consider the general equilibrium (direct and indirect) effects of χ^* on the traditional wage in the North and South, respectively.

$$\frac{dw}{d\chi^*} = \frac{\partial w}{\partial \chi^*} + \frac{\partial w}{\partial \overline{\theta}}\frac{d\overline{\theta}}{d\chi^*} = \frac{\partial w}{\partial \chi^*}\left[\left(1 - \frac{(1-\overline{\theta})\frac{\partial n_t}{\partial \overline{\theta}}}{(1-\overline{\theta})(n_m + \frac{\partial n_t}{\partial \overline{\theta}}) + \overline{\theta}(n_m - \frac{\partial n_t^*}{\partial \overline{\theta}})}\right) + \frac{\overline{\theta}}{D}\frac{\partial w}{\partial \overline{\theta}}\frac{\partial n_t^*}{\partial w^*}\right] > 0, \tag{65}$$

$$\frac{dw^*}{d\chi^*} = \frac{\partial w^*}{\partial \chi^*} + \frac{\partial w^*}{\partial \overline{\theta}}\frac{d\overline{\theta}}{d\chi^*} = \frac{\partial w^*}{\partial \chi^*}\left[\left(1 + \frac{\overline{\theta}\frac{\partial n_t^*}{\partial \overline{\theta}}}{(1-\overline{\theta})(n_m + \frac{\partial n_t}{\partial \overline{\theta}}) + \overline{\theta}(n_m - \frac{\partial n_t^*}{\partial \overline{\theta}})}\right) - \frac{(1-\overline{\theta})}{D}\frac{\partial n_t}{\partial w}\frac{\partial w}{\partial \chi^*}\right] > 0. \tag{66}$$

In deriving expressions (65) and (66), we substituted $\frac{d\overline{\theta}}{d\chi^*}$ from (58), D from (44), and used (45) and (56) to determine signs of various partial derivatives appearing in these expressions.

Parts (iv) and (v) of Proposition 5 follow directly from (65) and (66), respectively. Accordingly, an increase in Southern worker effort caused by an increase in χ^* makes workers in the South and North better off by raising the traditional wage in each region. This completes the proof of Proposition 5.

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