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Does Theory Fit the Facts?

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JAEWON JUNG, JEAN MERCENIER

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TEPP - Institute for Labor Studies and Public Policies  
TEPP - Travail, Emploi et Politiques Publiques - FR CNRS 3126



# Routinization-Biased Technical Change, Globalization and Labor Market Polarization: Does Theory Fit the Facts?

Jaewon Jung\* and Jean Mercenier†

This version: September 2010‡

## Abstract

There is now ample evidence that jobs and wages have been polarizing at the extremes of the skill distribution since the early 90s. Autor, Levy and Murnane (2003) have suggested that this might be due to technology substituting more easily for labor in performing routine rather than non-routine tasks. Other potential explanations include globalization. Active empirical research has now identified important stylized facts. The aim of this paper is to provide a theoretical exploration of alternative potential causes to this labor market polarization, and to identify which, if any, are consistent with the stylized facts.

*Keywords:* Skill Demands, Job Tasks, Polarization, Inequality, Technological Change, Routinization, Offshoring

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\*RWTH Aachen University and THEMA, U. de Cergy-Pontoise. <Jung@wiwi.rwth-aachen.de>.

†ERMES, Université Panthéon-Assas (Paris 2), <Jean.Mercenier@u-paris2.fr>.

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# 1 Introduction

The most widely accepted explanation for the spectacular rise of wage inequalities since the late 70s builds on the role of technology transformation that would be biased in favor of skilled workers and against unskilled workers. See Katz and Autor (1999) for a survey of this literature. Evidence of a slowing of overall wage inequality growth over the last 15 years, however, has induced questioning of this skill-biased technical-change (SBTC) explanation, with some authors strongly emphasizing changes in institutions (such as minimum wages and changes in unionization rates) as the more likely exogenous driving force behind the transformation of the U.S. wage structure: see *e.g.* Card and DiNardo (2002) and Lemieux (2006). But Autor, Levy and Murnane (2003) convincingly argue for a more nuanced way of understanding the impact of technology on the labor market: technology – and computers in particular – can replace labor in routine tasks – that is, in tasks that can be codified into repetitive step-by-step procedures – but not in non-routine tasks. Using U.S. data, they provide evidence in favor of their routinization-biased technical change assumption (hereafter, RBTC).

More recently, Goos and Manning (2007) have shown that those tasks that are typically non-routinizable tend to be concentrated at the two extremes of the skill distribution, and that employment shares have significantly grown in both of these activities during the last 25 years in the U.K. This phenomenon they refer to as “job polarization” is clearly consistent with the RBTC hypothesis, and they supply evidence of this against other potential explanations. Many authors have since then confirmed job polarization as a stylized fact common to most developed economies: see among others, Autor, Katz and Kearney (2006) for the U.S.; Spitz-Oener (2006) and Dustmann, Ludsteck and Schönberg (2009) for Germany; Goos, Manning and Salomons (2009) for most European economies.

Interestingly, Goos and Manning (2007) have also observed in the U.K. that the rise in the number of low-skill low-paid jobs has coincided with a decline in their pay relative to those in middling jobs where employment has fallen. This, as they note, does not entirely fit with the RBTC explanation except if the relative fall of measured-in-efficiency-units wages in routine tasks is being veiled by a disproportionate displacement out of those jobs by workers with relatively poor skills. This raises the question: are such composition

effects consistent with RBTC?

In their analysis of U.S. labor markets, Autor, Katz and Kearney (2006) also show that wage inequalities have ceased growing (and for some measures have even narrowed) in the bottom half of the distribution since the late 80s, while no significant change in trend is observed for upper-half inequality. Thus, wage polarization is a third salient feature of labor markets in the 90s.

We also know that this slowing in the growth of overall wage inequality emerges mainly from between-group adjustments: as forcefully shown by Lemieux (2006), residual (within-group) inequality –i.e., inequalities among observationally equivalent workers– has continued to rise in the U.S. during the 90s. This is another important stylized fact that needs to be explained if one wants to understand the current transformations of the labor market.

Our aim in this paper is to provide a theoretical exploration of the general equilibrium effects of the RBTC assumption, and to establish whether it can, as an exogenous driving force, account for the stylized facts stated above, that is: *i) job polarization, ii) a monotonous increase of average wages with the skill intensity of jobs, iii) wage polarization and iv) steady rise of within-group (residual) wage inequality.* We also want to understand, within a unified theoretical framework, the likely consequences of other competing assumptions that have been proposed in the literature, hopefully to be able to conclude on which is the more likely cause of recent labor market transformations. Finally, we wish to identify potential testable differences that may stimulate empirical investigations.

For this, we develop a multi-task based two-sector general equilibrium model with explicit distinction between labor skills and tasks. Labor supply is in the form of a distribution over a continuum of skills, so we avoid the usual somewhat arbitrary exogenous distinction between skilled and unskilled labor. Workers perform a finite set of tasks within firms which have heterogeneous technologies from which well defined skill demands are generated; workers endogenously sort themselves between these tasks according to their respective comparative advantage. We are therefore able to account for labor movements in and out of tasks, and to measure the effect of these employment changes on equilibrium (measured-in-efficiency-units) wages, as workers skill up-grade or skill down-grade depending on the production technologies they end up operating. The framework is fit to highlight within-task endogenous composition effects, so that individual wage changes can

be contrasted to average wage changes, and between-group inequality adjustments can be distinguished from residual (within-group) inequality adjustments. The general equilibrium structure takes full account of interactions between labor and product markets, so that we are able to evaluate how likely it is that demand-composition shifts may cause labor market transformations consistent with the stylized facts. Finally, we open our economy to trade, acknowledging the possibility for firms to choose whether or not to offshore or outsource the production of some of their intermediate input tasks to cheap labor countries. This makes it possible to explore the role of globalization in shaping today's labor markets, and to confront this, in a single consistent set-up, to other potential causes. The model is adapted from our previous work on offshore outsourcing (Jung and Mercenier, 2008), itself firmly rooted in Yeaple (2005).

A few theoretical efforts have been made prior to ours to rationalize recent empirical findings on labor market transformations, and they differ significantly from this paper. Building on Autor, Levy and Murnane's (2003), Autor, Katz and Kearney (2006) present a simple technology structure to illustrate how in this partial equilibrium setting, the fall of computer capital prices can induce labor market polarization when capital and labor employed to perform routine tasks are close substitutes. Building on Weiss (2008), Autor and Dorn (2009) develop a substantially more elaborate general equilibrium framework to predict labor market consequences of increased computerization of routine tasks. They however keep exogenous the dichotomy between skilled and unskilled labor, an assumption that is not particularly realistic for the period of interest (as they themselves acknowledge<sup>1</sup>), and also somewhat inappropriate when the focus is on the tasks performed by workers. Consequently, their analysis concentrates exclusively on the lower-tail distribution of employment and wages. Furthermore, due to a somewhat questionable assumption that the unskilled have either homogeneous or heterogeneous skills depending on which type of tasks they perform, their model generates rather counter-intuitive predictions on within-group inequalities.<sup>2</sup> Finally, they do not address the role of other potential driving

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<sup>1</sup>See page 17; as they report, the non-college share of worked hours has fallen from 58 to 38 percent in the U.S. between 1980 and 2005.

<sup>2</sup>As more low-skill workers self-select into the service occupations, within wage inequality decreases in routine tasks (by a simple compositional effect), while it is constant in manual tasks.

force explanations, in particular the role of globalization.<sup>3</sup>

The paper is organized as follows. In the next section, the core structure of our model is laid down. Using this closed economy setting, we explore in Section 3 and 4 the effects of technology based explanations – RBTC and SBTC, and compare these to those induced by demand-composition shifts. In Section 5, we extend the model to an open economy with multinationals adopting offshore outsourcing as their optimal business strategy; in this new environment, we re-address the issue of RBTC and confront its effects with those of rising globalization. We supplement our theoretical discussion with illustrative numerical simulations in Section 6, and offer a brief conclusion in Section 7.

## 2 The closed economy model

### 2.1 Households

Households have Cobb-Douglas preferences combining two sets of consumption goods,  $X$  and  $Y$ .<sup>4</sup> Industry  $X$  supplies a continuum of differentiated products, whereas goods from industry  $Y$  are homogeneous. We write:

$$Con = \beta \ln X + (1 - \beta) \ln Y \quad 0 < \beta < 1 \quad (1)$$

$$X = \left[ \int_{i \in N} x^d(i)^\rho di \right]^{\frac{1}{\rho}} \quad 0 < \rho < 1 \quad (2)$$

where  $x^d(i)$  denotes consumption demand for the  $i$  variety of products from sector  $X$  and  $\sigma = 1/(1 - \rho)$  is a constant differentiation elasticity.<sup>5</sup> Maximizing utility subject to income

<sup>3</sup>In a recent conference (BIBB-IAB TASKS Workshop, Nürnberg, May 2010) where this paper was presented, David H. Autor, in a keynote presentation, sketched a theoretical model (based on some ongoing joint work with Daron Acemoglu) that bears similarities with ours, but also has some important differences. Contrary to us, they assume three different skill levels and a continuum of tasks, so they are unlikely to be able to account for changes in within-group (residual) inequalities –that is inequalities among observationally equivalent workers– which is an important feature of recent labor markets (as they themselves previously emphasized: see Acemoglu 2002, p.10). Also, they develop essentially a closed economy framework that is unlikely to be able to disentangle the effects of technological change from those of rising globalization.

<sup>4</sup>The assumption of Cobb-Douglas preferences is made for convenience only; the only necessary restriction on preferences is that the consumption goods not be inferior goods.

<sup>5</sup>This description of the  $X$  industry might seem unnecessarily complicated. Indeed, in our closed economy setting, treating  $X$  as a homogeneous competitively produced good does not qualitatively affect the

(*Inc*) immediately yields the following demand system:

$$x^d(i) = \left( \frac{P_X}{p(i)} \right)^\sigma \frac{\beta Inc}{P_X} \quad (3)$$

$$P_X = \left[ \int_{i \in N} p(i)^{1-\sigma} di \right]^{\frac{1}{1-\sigma}} \quad (4)$$

$$p_Y Y = (1 - \beta) Inc. \quad (5)$$

Households also supply labor; there is a continuum of workers differentiated by their skill level  $z$  with cumulative exogenously given distribution  $G(z)$  on support  $[z_{min}, z_{max}]$ .<sup>6</sup> Finally, households own a given stock of capital.

## 2.2 Firms and the labor market

Industry  $Y$  is perfectly competitive. We have in mind here the production of tasks that are typically interactive and therefore cannot be routinized, even though they require poorly qualified labor. Examples of such service occupations include taxi driving, cleaning, home health caring, etc.<sup>7</sup> The technology used for producing these tasks is assumed Ricardian (i.e., with constant unit coefficient) in labor, with marginal cost  $C_Y$ .

In the  $X$  industry, each final-good variety is produced in amount  $x(i)$  by a single firm. These goods are substantially more sophisticated than the  $Y$  aggregate, so that production of each of these varieties involves a fixed cost  $F_L$  before two types of complementary input activities can be combined, respectively in amount  $l(i)$  and  $m(i)$ . The first intermediate input groups all non-repetitive cognitive tasks, that are generally associated with white-collar headquarter services. Because these tasks are not easily routinizable, they cannot be performed by machines but only by relatively skilled labor operating with a technology that we shall assume Ricardian. In contrast, the second input includes all tasks that are

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conclusions. Increasing returns to scale technologies and imperfect competition are however important ingredients of the globalization process; product differentiation then becomes both realistic and convenient when modeling offshore outsourcing decisions by multinational firms in the open economy. Treating industry  $X$  as producing non homogeneous goods here, both eases the exposition and ensures full comparability between the closed and the open economy versions of the model.

<sup>6</sup>See Blanchard and Willmann (2008) for an effort to endogenize this skill distribution through investment decisions in education by individuals.

<sup>7</sup>Service occupations accounted for slightly less than 15% of employment in the US in 2005, a share that has been growing at a spectacular pace between 1985 and 2005: see Autor and Dorn (2009, Table 1).

repetitive by nature, be they manual or cognitive; these include most blue-collar jobs but also a significant subset of (possibly sophisticated) white collar jobs such as bookkeeping. Because these tasks are easily routinizable, they can be performed almost equally well by machines or by workers. We emphasize this by assuming that capital and labor enter as perfect substitutes in the Ricardian technology used for producing intermediate input tasks  $m(i)$ . Units in which both intermediate inputs are measured is innocuous and can be chosen so that the production function writes as:

$$x(i) = l(i) = m(i). \quad (6)$$

The marginal costs of producing the two intermediate inputs are denoted  $C_L$  and  $C_M$  respectively. Note that  $C_Y$ ,  $C_M$  and  $C_L$  are the measured-in-efficiency-units wages associated with each task type.

An individual worker's productivity will reflect both its own skills, and the type of task he is hired to perform. Let  $\varphi_j(z)$  denote the productivity of a worker of skill  $z$  when performing task  $j \in \{Y, M, L\}$ .  $\varphi_j(z)$  is continuous and increasing in  $z$  so that a higher skilled worker is absolutely more productive than a less skilled one when performing the same task. We also assume that more talented workers have a comparative advantage in performing more sophisticated tasks so that

$$0 < \frac{d \ln \varphi_Y(z)}{dz} < \frac{d \ln \varphi_M(z)}{dz} < \frac{d \ln \varphi_L(z)}{dz}, \quad (7)$$

with  $\varphi_j(z_{\min}) = 1$ ,  $j \in \{Y, M, L\}$ . Thus, with competitive labor markets, workers will in equilibrium sort between the three types of activities according to their respective comparative advantage. Let  $z_0$  and  $z_1$  be equilibrium skill thresholds with  $z_{\min} < z_0 < z_1 < z_{\max}$ . Then, the least skilled workers, those with  $z \in [z_{\min}, z_0)$ , will be employed in service occupations producing  $Y$ , those with talents  $z \in [z_0, z_1)$  will be hired to perform repetitive tasks within  $X$ -firms, and the most talented, those with  $z \in [z_1, z_{\max}]$  will be allocated to non-repetitive cognitive activities in headquarters. Figure 1 summarizes these assumptions for the case of log-linear functional forms, which we shall hereafter assume.

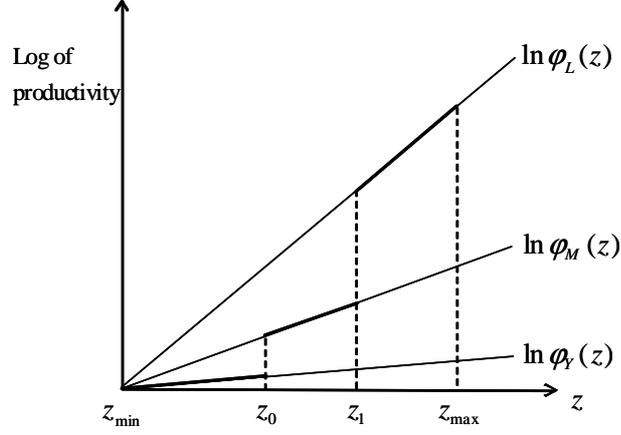


Figure 1: The three technologies.

Workers are paid at their marginal productivity, so the wage distribution will satisfy

$$w(z) = \begin{cases} C_Y \varphi_Y(z) & z_{\min} \leq z < z_0 \\ C_M \varphi_M(z) & z_0 \leq z < z_1 \\ C_L \varphi_L(z) & z_1 \leq z \leq z_{\max}. \end{cases} \quad (8)$$

Individuals with skills  $z_0$  and  $z_1$  have, in equilibrium, no incentive to relocate between tasks, a no-arbitrage condition that ties together the wages  $C_j$ ,  $j \in \{Y, M, L\}$ :

$$\begin{aligned} C_Y \varphi_Y(z_0) &= C_M \varphi_M(z_0) \\ C_M \varphi_M(z_1) &= C_L \varphi_L(z_1). \end{aligned} \quad (9)$$

Choosing  $C_Y$  as the numeraire, these two indifference conditions fix the wages in the  $X$  industry:

$$C_M = C_Y \frac{\varphi_Y(z_0)}{\varphi_M(z_0)} \quad (10)$$

$$C_L = C_M \frac{\varphi_M(z_1)}{\varphi_L(z_1)}. \quad (11)$$

Observe from (7) that  $C_Y > C_M > C_L$  and that  $C_M$  and  $C_L$  are decreasing respectively in  $z_0$  and  $z_1$ . The resulting equilibrium wage distribution is illustrated in Figure 2.

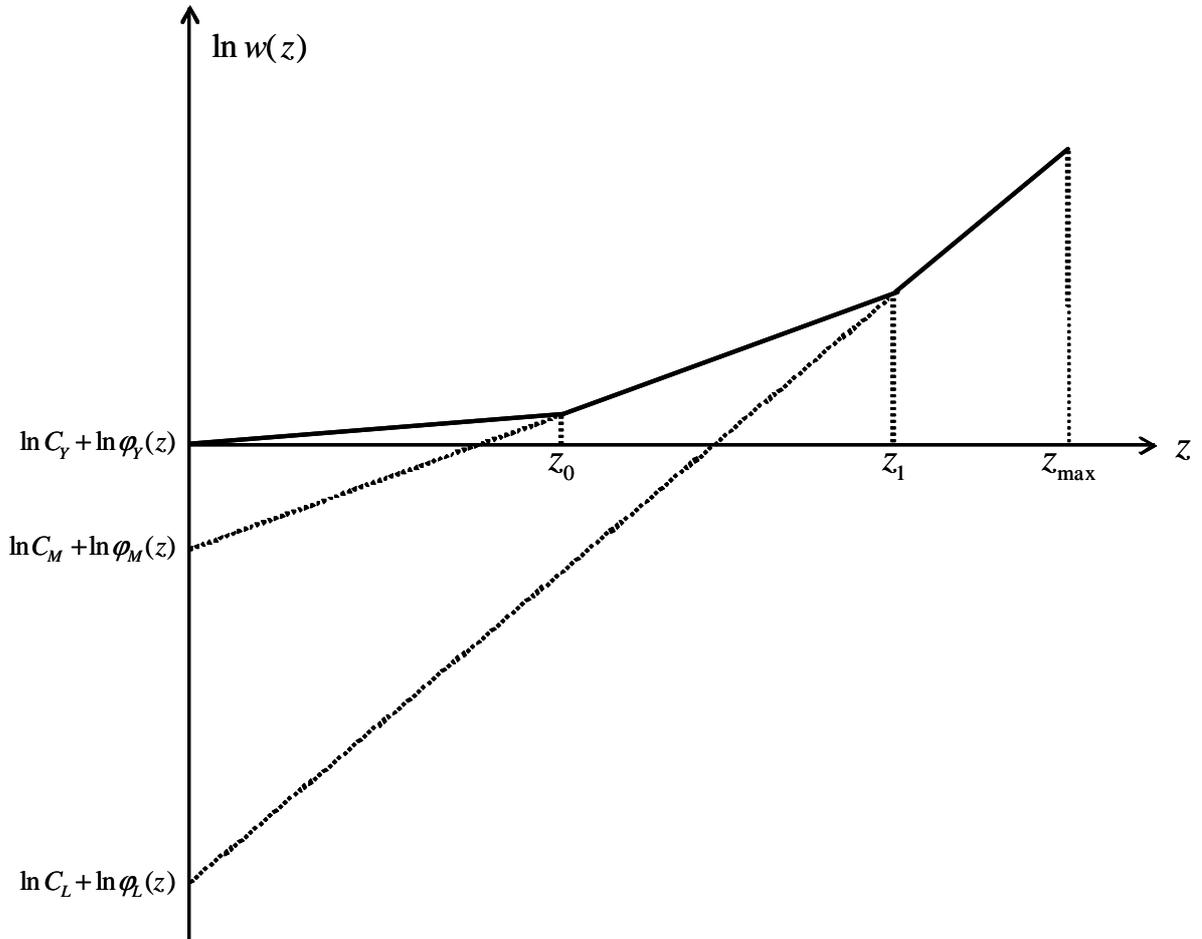


Figure 2: The equilibrium wage distribution.

Marginal cost pricing holds in competitive  $Y$  activities so that  $p_Y = C_Y$ . Following Krugman (1981), we assume that monopolistic competition prevails between symmetric firms producing different varieties of  $X$ ; with Dixit-Stiglitz preferences (2) it is optimal for each producer to charge a constant mark-up rate  $\frac{\sigma}{\sigma-1}$  over marginal cost; the symmetry assumption ensures that all varieties will have the same price:

$$p_L = p(i) = \frac{\sigma}{\sigma-1} (C_L + C_M) \quad i \in N_L \quad (12)$$

where  $N_L$  is the number of producers.

### 2.3 Equilibrium

The equilibrium skill threshold  $z_0$  determines employment in service occupations that will satisfy the demand for the  $Y$ -good:

$$\int_{z_{\min}}^{z_0} \varphi_Y(z) dG(z) = Y. \quad (13)$$

In the  $X$  industry, each firm satisfies the demand for its own final variety, so that

$$x_L = x(i) = x^d(i) \quad i \in N_L. \quad (14)$$

We assume free entry, so that there are no extra-normal profits, and mark-up revenues will exactly cover fixed costs. We can, for convenience, express the fixed costs in the form of foregone output, so that  $F_L$  is priced using (12). As is easily shown, the zero profit condition requires that

$$\frac{1}{\sigma} p_L x_L = (C_L + C_M) F_L. \quad (15)$$

Observe, by combining (12) and (15), that the individual firm's output is constant and proportional to its fixed costs. This is quite convenient because it implies that changes in the industry market-size will affect the number of firms  $N_L$  only, without inducing within firm adjustments.

The total amount of labor used in the production of headquarter services follows from the technology (6):

$$\int_{z_1}^{z_{\max}} \varphi_L(z) dG(z) = N_L (x_L + F_L), \quad (16)$$

and repetitive tasks are exclusively concentrated within  $X$ -firms, so that:

$$\kappa_M \int_{z_0}^{z_1} \varphi_M(z) dG(z) = \int_{z_1}^{z_{\max}} \varphi_L(z) dG(z) \quad (17)$$

where  $\kappa_M > 1$  accounts for the contribution of capital: conditions (16) and (17) determine the equilibrium skill thresholds  $z_1$ . Finally, income follows from full employment:

$$Inc = C_Y \int_{z_{\min}}^{z_0} \varphi_Y(z) dG(z) + \kappa_M C_M \int_{z_0}^{z_1} \varphi_M(z) dG(z) + C_L \int_{z_1}^{z_{\max}} \varphi_L(z) dG(z). \quad (18)$$

This completes the description of our general equilibrium model.

### 3 Routinization-biased technical change (RBTC)

We now turn to a formal definition of routinization-biased technical change, and analyze its effects on the labor market. We want to capture the effects of the ongoing fall in the cost of computerizing routine tasks on the production process within firms. We interpret RBTC as a positive supply shock on capital –a rise of  $\kappa_M$  in (17)– that will substitute out labor in the production of repetitive tasks; furthermore, because this capital embodies technical progress, it is also likely to push up the relative productivity of the more talented workers by raising the slope of the skill-productivity profile in  $M$ -activities of Figure 1.<sup>8</sup>

To understand how RBTC will affect the equilibrium wage distribution in Figure 2, we focus on how the skill thresholds  $z_0$  and  $z_1$  are being displaced. Consider first the effects of a steeper productivity schedule  $\ln \varphi_M(z)$ . At the initially given skill distribution of jobs (keeping  $z_0$  and  $z_1$  temporarily fixed), the productivity induced wage increase in routine tasks will spread to all headquarter workers as the efficiency-unit wage  $C_L$  rises to match the wage of the most talented  $M$ -worker:  $d \ln C_L = d \ln C_M \varphi_M(\bar{z}_1) > 0$ . From (17), however, it is apparent that, for  $z_0$  given,  $z_1$  has to be reduced to restore the balance between input tasks within the  $X$  industry: the new technology forces  $X$ -firms to relocate the best among workers in repetitive  $M$ -tasks to headquarter activities where they will perform  $L$ -type tasks making use of the more efficient  $L$ -technology, and therefore earn better wages. This skill-upgrading of workers contributes to push  $C_L$  further up. Observe that the impact on  $p_L$  is yet ambiguous because  $C_M$  has fallen. For given  $z_0$ , more abundant computer capital ( $d\kappa_M > 0$ ) can only amplify the movement of workers from  $M$  to  $L$  tasks within  $X$ -firms:  $z_1$  is further shifted to the left with relative wages of all workers in non-repetitive tasks rising as skill-upgrading of less talented workers proceeds. At this stage, it is clear that both employment and wages (measured in efficiency units) have risen in  $L$  activities and fallen in repetitive tasks  $M$ .  $z_0$ , however, is not an equilibrium threshold: the  $Y$  good is obviously now in relative scarce supply, so that its price has to rise (that is,  $C_M$  and  $C_L$  have to fall in equal proportion relative to the numeraire  $C_Y$ ), making it possible for producers in the  $Y$  industry to offer better wages and attract workers

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<sup>8</sup>To ensure a unique interior solution requires that the new productivity schedule complies to restrictions (7).

previously employed in repetitive intermediate  $M$ -tasks: the threshold  $z_0$  is being pushed to the right as these workers skill-downgrade. This induced expansion of the  $Y$ -sector tends to mitigate the initial leftward shift of  $z_1$ , obviously without qualitatively affecting the mechanism described (the assumption that  $Y$  is a non-inferior good ensures that both the price and the output volume will adjust upward). Figure 3 displays how RBTC has affected the equilibrium wage distribution.

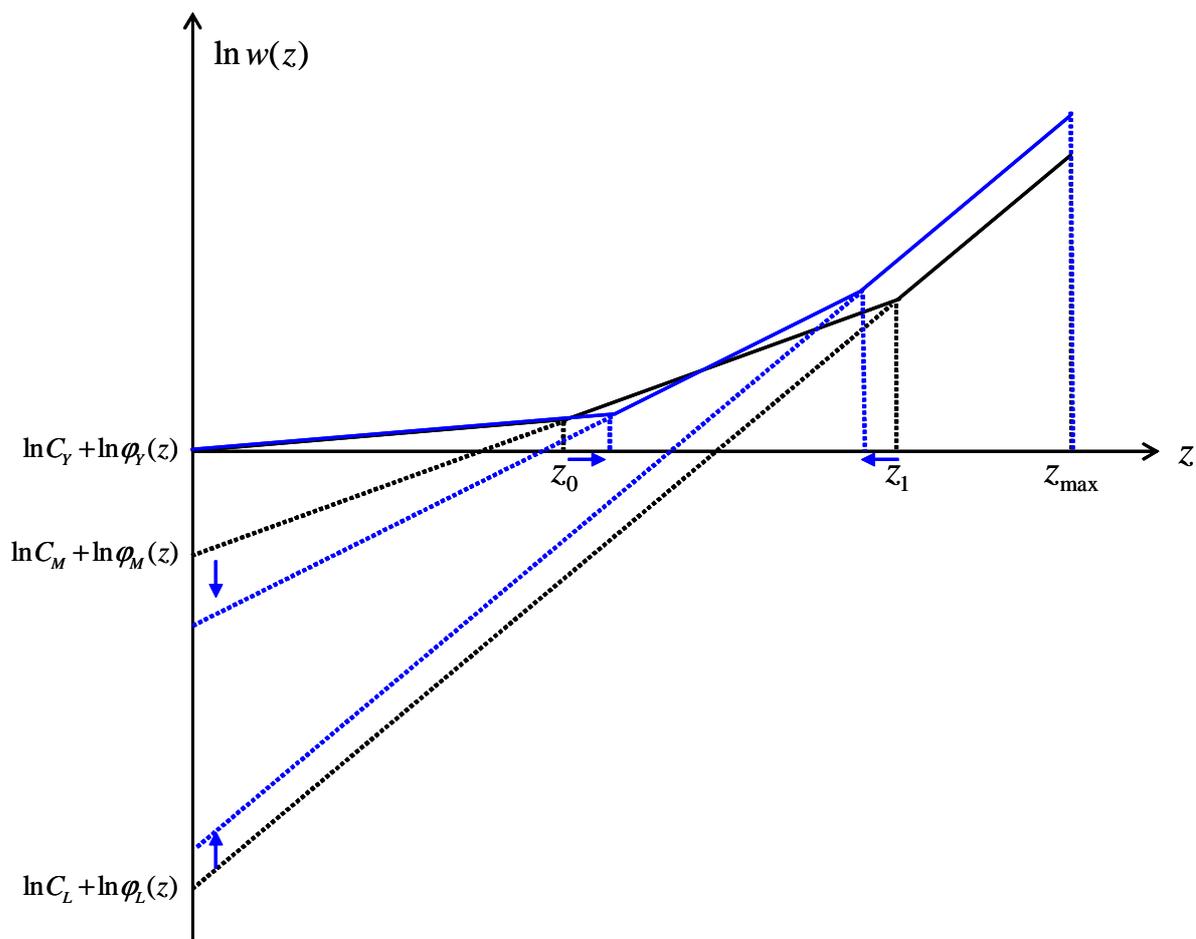


Figure 3: The effects of RBTC on the equilibrium wage distribution.

RBTC has generated unambiguous job polarization: a shrinking share of employment in intermediate repetitive activities, with a labor force being increasingly concentrated in the lowest and in the highest wage occupations, both characterized by the non-routinizable nature of the performed tasks. Wages have also unambiguously polarized, consistently with the stylized facts with  $d \ln C_L > d \ln C_Y = 0 > d \ln C_M$ :  $M$ - to  $Y$ - relative wages fall, and

those in headquarter activities increase relative to those in both  $M$  and  $Y$  tasks.

What can be said on the effect of RBTC on average wages by occupations? With  $z_0$  being shifted to the right, the average wage unambiguously rises in  $Y$ -type tasks. Indeed, (even though for those individual workers this is a skill-downgrading move associated with a wage loss,) they come with better skill endowments than those previously engaged in performing those tasks and therefore contribute positively to the average wage in  $Y$ .<sup>9</sup> In the other occupations, however, the sign of average-wage changes is ambiguous because of composition effects. Indeed, though individual wages have risen for all who now work in headquarter jobs, those newly hired to perform non-repetitive cognitive tasks are less talented. The same ambiguity prevails in occupations  $M$  because workers that move out of the repetitive-type activities do so either by skill-upgrading or by skill-downgrading, and are respectively the most- and the least- talented originally employed to perform these tasks. This highlights the difficulty of associating technical change to average productivity growth even with task-level disaggregation: the only tasks here that display unambiguous average productivity gains experience no technical change, even though individual workers here earn either unchanged or lower wages than before. We nevertheless conclude that the RBTC assumption can indeed induce the composition effects necessary to fit the second stylized fact.

Observe that RBTC generates changes in wage inequalities that are broadly consistent with observed recent trends reported by Autor, Katz and Kearney (2006): a rise in the upper-half inequality, as measured by the 90-50 log-wage differential, results unambiguously, whereas changes in the lower-half inequality will typically be much lower.<sup>10</sup> More remarkable is the prediction that wage inequalities unambiguously rise among observationally equivalent workers performing identical tasks. Our model therefore offers an explanation for the well documented fact that overall and within-group wage inequality

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<sup>9</sup>This prediction is quite consistent with the often reported observation that an increasing proportion of middle-skilled people report that they are employed in jobs for which they are overqualified. See *e.g.* Green and McIntosh (2007).

<sup>10</sup>A contraction in the 50-10 log-wage differential, as has been observed in the U.S. economy between 1987 and 2004 (Autor, Katz and Kearney, 2006), could also be obtained in this simple two sector model, but it would result from a special choice of technology gaps between activities and/or of initial relative positions of the equilibrium skill thresholds.

growth have been changing in a very disproportionate way (and for some measures even in opposite directions), and demonstrates how these observations can be reconciled under RBTC.

We have, up to now, ignored the skill-biased technical change (SBTC) assumption. It has become evident from the literature about job polarization that the most important difference between RBTC and SBTC is their prediction about employment and wage growth at the lower end of the skill distribution. SBTC predicts that, the lower the skill-level required to perform a job, the easier it is for new machines to substitute for labor. In the context of this model at least, it is straightforward to understand why SBTC is very unlikely to be the cause of the recently observed transformations of the labor market. To see this, consider the possibility that capital enters the production function for  $Y$  as a perfect substitute for low-skilled labor; equilibrium equation (13) then becomes:

$$\kappa_Y \int_{z_{\min}}^{z_0} \varphi_Y(z) dG(z) = Y \quad \kappa_Y > 1 \quad (19)$$

with income definition (18) modified accordingly. Assume  $d\kappa_Y > d\kappa_M > 0$ ; for given  $z_0$ , the  $X$ -good is now in relative scarce supply, so that  $P_X/P_Y$  will rise; producers of  $X$ -varieties experience positive extra-normal profits so that new firms enter the market. This increases competition for labor and measured-in-efficiency-units wages will rise in that sector. The best workers previously employed in service occupations find it attractive to move to  $X$ -firms where they skill-upgrade and earn better wages:  $z_0$  shifts left, as well as  $z_1$  (the latter in order to restore the balance between  $M$  and  $L$  input tasks) so that  $0 < d\ln C_M < d\ln C_L$  until product market equilibrium is restored. SBTC has eroded employment in low-skill tasks, increased employment in other activities, and unambiguously shifted the wage distribution in favor of the more talented workers. Assuming, in addition, that the technical progress embodied in the new machines also increases more the slope of the skill-productivity schedule in the production of the  $Y$  tasks ( $d\ln \varphi_Y(z) > d\ln \varphi_M(z) > 0$ ) can only reinforce the adjustment mechanism just described. SBTC is indeed clearly inconsistent with labor market polarization.

## 4 Demand-composition shifts

Polarization could however be driven by factors other than technology. Demographic trends, for instance, are likely to induce demand composition shifts: an ageing population will increase its expenditure shares for services such as outside-family care and hospital assistants, which are mainly non-routinizable tasks performed by low-skilled low-paid workers. Also, it has been suggested (Manning, 2004) that rising wage inequalities may have contributed to displace demand in favor of low quality jobs because of the relatively high income elastic nature of demand for services such as child care. How will such shift in preferences impact on the labor market? The answer is provided in Figure 4, where it is shown that neither job nor wage polarization can result from such a change.

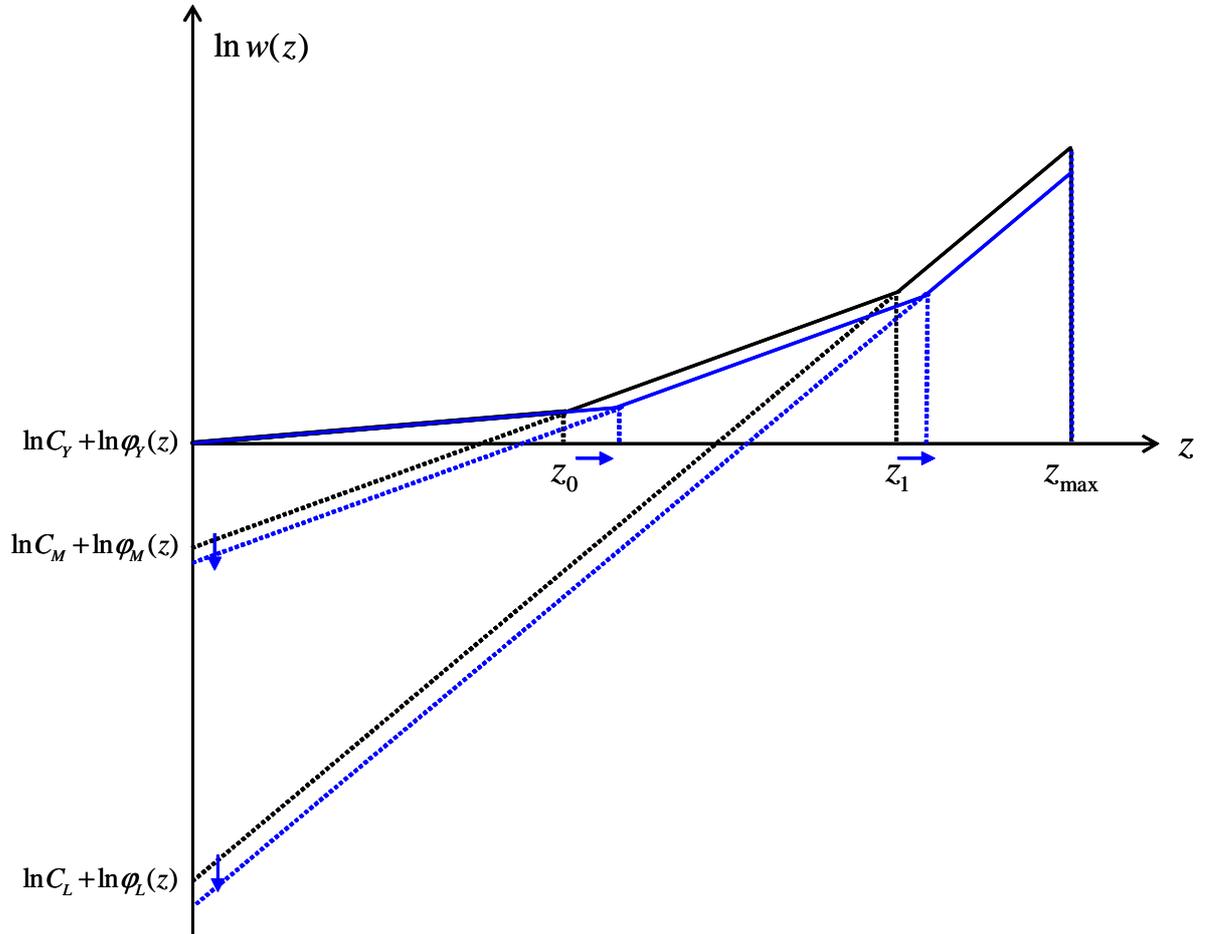


Figure 4: The effect of a preference shift in favor of service occupations.

To understand why, consider the effects of an exogenous reduction of  $\beta$  in (1). The

impact effect is to increase the relative price of the competitive good, as well as wages for those tasks ( $d \ln C_M = d_1 \ln C_L < 0$ ), making it attractive for lower-skilled  $M$ -task workers to skill-downgrade by moving into the  $Y$  jobs:  $z_0$  shifts to the right.  $X$ -firms are forced into restructuring, reducing wages in oversized headquarter activities ( $d_2 \ln C_L < 0$ ); the least talented among the workers engaged in such activities now find it profitable to skill-downgrade and perform  $M$ -tasks:  $dz_1 > 0$ . In equilibrium therefore, aggregate employment in cognitive non-repetitive tasks cannot have expanded, and workers performing those tasks have experienced wage losses more important than in other activities. Clearly, neither job polarization nor wage polarization is a possibility here.

## 5 Globalization

The impact of globalization on labor markets is also potentially considerable. Drastic advances in transportation and communication technologies coupled with institutional progress in many cheap labor countries provide firms in the North with strong new incentives to extensively adopt offshore outsourcing strategies and transfer larger parts of their production activities to the South. There is ample evidence that this transfer is biased towards dominantly routine –blue-collar as well as white-collar– tasks. It seems therefore that the computerization of routine tasks and the rise of offshore outsourcing tend to contribute in a similar way to the recent transformations of the labor market in the North. Our simple model can easily be extended to shed some light on the role of offshore outsourcing in the shaping of labor markets.

### 5.1 Extending the model: multinationals and offshore outsourcing

Each multinational firm produces a specific variety of the  $X$ -good –the description of the domestic household part of the model is therefore unaffected– combining two complementary inputs using a Leontief technology similar to (6). Assume now that there are two competing technologies available for producing headquarter services, a high- ( $H$ ) and a low- ( $L$ ) technology. Technology  $H$  is more expensive to set-up but cheaper to operate than tech  $L$  so that  $F_L < F_H$  and  $C_L > C_H$ , where  $F_j$  and  $C_j$  denote respectively fixed

and marginal costs of production,  $j = L, H$ . Though headquarter services can only be produced domestically, repetitive intermediate tasks can be either performed locally or offshored. In the home country, as before, they involve using an  $M$  technology with marginal cost  $C_M$ ; performed in the South, these activities have a lower unit production cost  $C_M^* = \theta C_M$ ,  $\theta < 1$ . But offshore outsourcing involves specific fixed costs  $F_I$  so that only the most productive  $X$ -firms can turn multinational. There is ample empirical evidence that, everything else equal, multinationals (MNEs) are systematically more efficient than non-MNEs.<sup>11</sup> We can therefore assume  $F_I$  and  $\theta$  such that, in equilibrium, only firms using the  $H$  technology find it profitable to offshore the production of their repetitive intermediate tasks; domestic-only  $L$ -firms are therefore as described in our closed economy setting.

The best workers have an absolute advantage over less talented rivals on any technology, and a comparative advantage for performing high tech tasks  $H$ : the productivity functions  $\varphi_j(z)$   $j = L, H$  satisfy:

$$\frac{d \ln \varphi_L(z)}{dz} < \frac{d \ln \varphi_H(z)}{dz}, \quad (20)$$

with  $\varphi_j(z_{\min}) = 1$ , so that, with competitive labor markets, the high- $z$  workers will be hired to perform nonrepetitive cognitive tasks within MNEs. Let  $z_2 \in (z_1, z_{\max})$  be the skill-threshold separating those headquarter workers that are employed in domestic only firms ( $z < z_2$ ) from those employed by MNEs. Then, the latter will earn  $w(z) = C_H \varphi_H(z)$ ,  $z_2 \leq z \leq z_{\max}$ , with the measured-in-efficiency-units wages  $C_L$  and  $C_H$  tied together by the indifference condition:

$$C_L \varphi_L(z_2) = C_H \varphi_H(z_2). \quad (21)$$

Observe that (20) ensures  $C_L > C_H$  and  $C_H$  decreasing in  $z_2$ . The resulting equilibrium wage distribution in this open-economy set-up with offshore-outsourcing MNEs is illustrated in Figure 5.

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<sup>11</sup>See *e.g.* Doms and Jensen (1998), Conyon, Girma and Wright (2002). Helpman, Melitz and Yeaple (2004) highlight that MNEs are substantially more productive than non-MNE exporters which outperform significantly purely domestic ones. See also Navaretti, Castellani and Disdier (2006) for a discussion, and some empirical evidence, on technological upgrading related to firms switching from national to multinational.

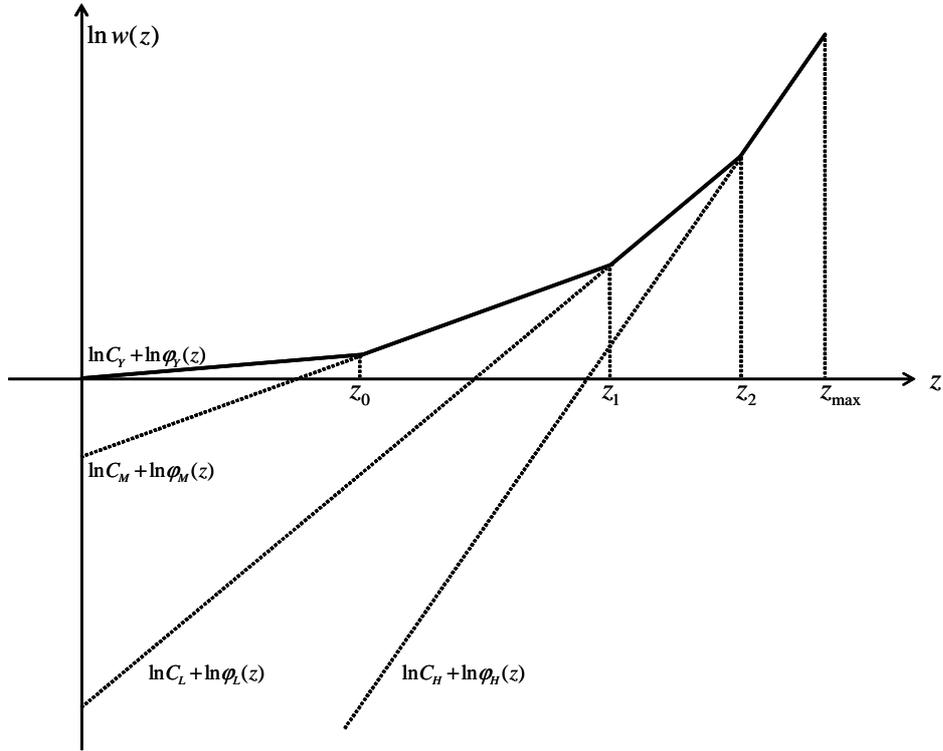


Figure 5: The open economy equilibrium wage distribution.

MNEs compete with domestic-only firms on monopolistically competitive product market; with preferences (2) they will charge constant mark-up rates; making the assumption of symmetry among MNEs implies that they will charge the same price and have the same output scale:

$$p_H = p(i) = \frac{\sigma}{\sigma - 1} (C_H + \theta C_M) \quad i \in N_H, \quad (22)$$

where  $N_H$  is the equilibrium number of MNEs necessary to ensure zero extra-normal profits:

$$\frac{1}{\sigma} p_H x_H = \frac{1}{\sigma} p(i) x(i) = (C_H + \theta C_M) \cdot (F_H + F_I) \quad i \in N_H. \quad (23)$$

(Here again, we have expressed real fixed costs in terms of foregone output volumes.) Observe that multinationals will charge lower prices than their national-only competitors, as realism suggests.

Equilibrium conditions (16) and (17) still hold after substitution of  $z_2$  for  $z_{max}$  in the integral signs; the total amount of domestic labor employed by MNEs follows from our

assumptions on technology similar to (6):

$$\int_{z_2}^{z_{\max}} \varphi_H(z) dG(z) = N_H (x_H + F_H + F_I). \quad (24)$$

Domestic income follows from full factor employment,

$$Inc = C_Y \int_{z_{\min}}^{z_0} \varphi_Y(z) dG(z) + \kappa_M C_M \int_{z_0}^{z_1} \varphi_M(z) dG(z) + C_L \int_{z_1}^{z_2} \varphi_L(z) dG(z) + C_H \int_{z_2}^{z_{\max}} \varphi_H(z) dG(z) \quad (25)$$

and foreign income from offshore activity by MNEs:

$$Inc^* = \theta C_M \int_{z_2}^{z_{\max}} \varphi_H(z) dG(z). \quad (26)$$

To avoid unnecessary balance of payment complications, we assume that  $Inc^*$  is spent entirely on  $X$ -goods from the North, with preferences identical to (2); each variety  $i$  is therefore exported in amount

$$x^{d^*}(i) = \left( \frac{P_X}{p(i)} \right)^\sigma \frac{Inc^*}{P_X} \quad i \in N = N_L \cup N_H \quad (27)$$

where  $P_X$  is given by (4). Each  $X$ -firm will in equilibrium satisfy the demand for its own variety, so that (14) becomes

$$x(i) = x^d(i) + x^{d^*}(i) \quad i \in N = N_L \cup N_H \quad (28)$$

which completes the open economy version of our model.

## 5.2 RBTC in the open economy

Before addressing the issue of rising globalization, we discuss how the presence of MNEs could possibly –though indeed somewhat unlikely– affect our previous assessment of the RBTC hypothesis. For this purpose, our closed economy reasoning can be replicated: clearly, nothing is changed as long as  $z_2$  is kept fixed. It is immediate to check that with  $z_2$  unchanged, the cost ratios  $C_M/C_M^*$  and  $C_L/C_H$  also remain unchanged, but not necessarily the output price ratio  $p_L/p_H$ : this will depend on the initial marginal input-cost shares. Changes in  $p_L/p_H$  will be  $\geq 0$  iff  $C_H \leq \theta C_L$ , that is, iff  $\varphi_L(z_2) \leq \theta \varphi_H(z_2)$ . Thus, at given  $z_2$ , if the technology gap between  $L$  and  $H$  firms is large enough,  $X$ -varieties from high-tech firms will be in relative scarcity: product market equilibrium requires

from these firms more output. Increasing the scale of offshored activities is no problem for multinational firms since labor is abundant enough in the South to leave unaffected the marginal production costs of these repetitive intermediate input tasks. In the home country, however, skilled labor has to be pulled out of the national-only competitors. Multinationals achieve this by offering better wages:  $z_2$  shifts leftward, hence amplifying the ongoing labor market polarization.<sup>12</sup> The wage increase granted to workers with  $z > z_2$  is passed over to  $p_H$ , inducing demand substitution that also contributes to restore product market equilibrium. This adjustment continues until the output price ratio  $p_L/p_H$  recovers its initial equilibrium value.<sup>13</sup> In this case, therefore, the conclusions reached for the closed economy are unaffected: the presence of multinational firms tends to amplify the labor market transformations induced by RBTC. This case is displayed in Figure 6.

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<sup>12</sup>Observe that, simultaneously, income rises in the South; this tends to bias aggregate final demand in favor of the  $X$  good, and to mitigate employment and wage growth at the lower end of the skill distribution. It is a second order effect, however, that does not affect the qualitative conclusions.

<sup>13</sup>Indeed, making use of (15) and (23), after substituting out prices and output (from (12), (22), (3), (27) and (28)), it is easy to show from the ratio  $\frac{p_L x_L}{p_H x_H}$  that, in equilibrium,  $\frac{C_L + C_M}{C_H + \theta C_M} = \left[ \frac{F_H + F_L}{F_L} \right]^{1/\sigma}$ , a constant.

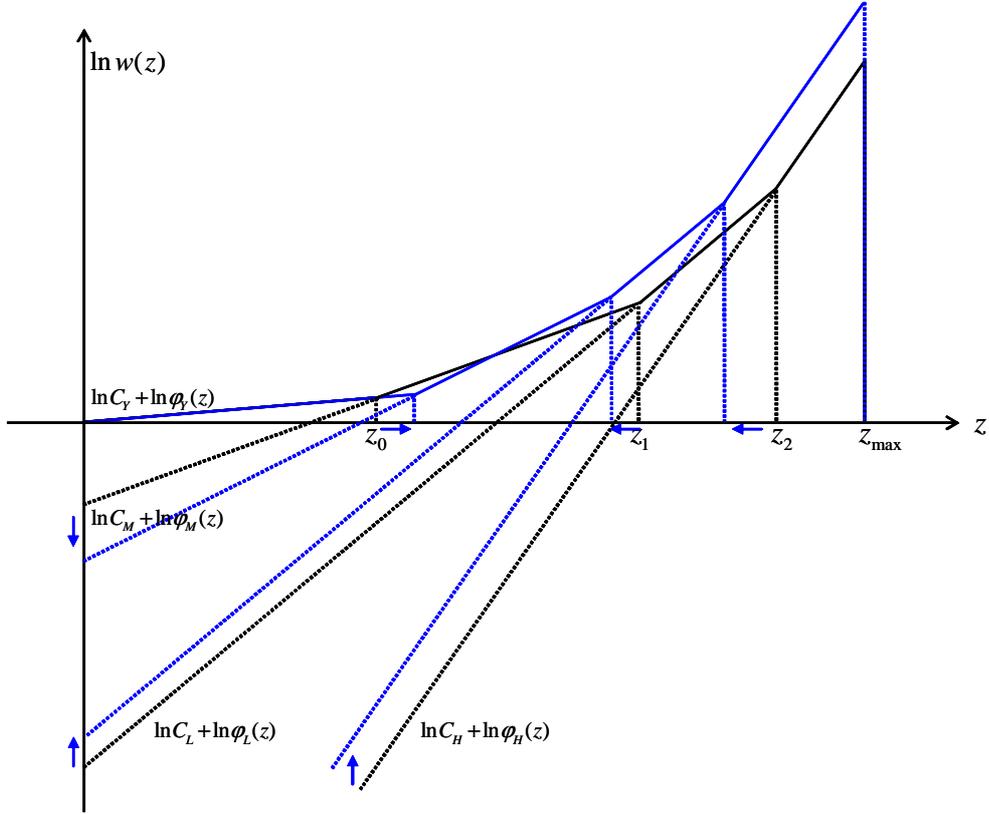


Figure 6: The effects of RBTC on the equilibrium wage distribution when the tech-gap between MNEs and non-MNEs is large enough.

This is not the only possible equilibrium outcome, however. Indeed, if the technology advantage of MNEs is not large enough, so that  $C_H > \theta C_L$ , at given initial  $z_2$ , RBTC produces a costs advantage in favor of national only firms: the price ratio  $p_L/p_H$  will have changed in favor of domestic only firms. Demand substitution forces MNEs to downscale their labor force:  $z_2$  moves to the right, and so does  $z_1$ . In this case, therefore, the impact of RBTC on the equilibrium job distribution is ambiguous. It will crucially depend on how substitutable  $L$  and  $H$  varieties are, that is, on the value of the preference parameter  $\sigma$ : the more  $X$ -varieties are differentiated ( $\sigma$  low), the more likely it is that RBTC will be consistent with the stylized facts.<sup>14</sup>

We have shown how difficult it is to generalize to the open economy conclusions on the role of technology in shaping labor markets drawn from a closed economy analysis.

<sup>14</sup>In the very special case where  $C_H = \theta C_L$ , the equilibrium ratio  $p_L/p_H$  is fixed and RBTC does not affect the relative competitiveness of MNEs and the equilibrium skill threshold  $z_2$  remains unchanged.

Things tend to be much more complicated in open economies: by their offshore outsourcing practices, MNEs will amplify, mitigate or even possibly counter, the direct effect of RBTC on the job and wage distributions. The productivity difference between MNEs and non-MNEs plays here a crucial role: the lower this difference, the less RBTC seems likely to cause labor market polarization. There is abundant evidence that multinationals are more productive than national-only firms (of course, after controlling for output scale). Is the tech-gap large enough to realistically make RBTC the main explanation? Before we venture an answer to that question, we have to understand the consequences of rising globalization on the labor market. This is what we now turn to.

### 5.3 Rising globalization

Rising globalization naturally takes two non-exclusive forms in this model: a fall of the fixed cost of engaging in offshore outsourcing activities ( $dF_I < 0$ ), and a reduction of marginal cost of producing repetitive tasks abroad ( $d\theta < 0$ ), the latter interpreted to include transportation costs.<sup>15</sup> Both shocks yield identical qualitative equilibrium effects –albeit through slightly different channels– so we focus our exposition on the first. Lower fixed costs  $F_I$  directly induce technology upgrading in the  $X$ -industry: an increasing number of low-tech producers find it profitable to turn multinational and switch to high-tech.<sup>16</sup> For given  $z_0$ , this induces a contraction of activity in national-only  $X$ -firms with  $z_1$  and  $z_2$  both being shifted to the left.<sup>17</sup> Some workers therefore become more productive by performing different tasks within the same domestic-only firms, and others by performing the same tasks but in a different more efficient MNE – a mechanism well documented by Head and Ries (2002), among others<sup>18</sup>. This simultaneous technology upgrading by

<sup>15</sup>Explicitly introducing ice-berg transportation costs is straightforward but only complicates without adding insight; it only affects income levels in the South.

<sup>16</sup>More rigorously, there is entry (exit) of high-tech (low-tech) firms. It can be shown –see Jung and Mercenier (2008)– that creations exceed destructions so that the total number of firms will increase, for given  $z_0$ .

<sup>17</sup>With a falling  $\theta$ , the mechanism is slightly less direct: the price ratio  $p_L/p_H$  rises inducing demand substitutions within the  $X$  industry, away from  $L$ -varieties. The size of MN activities will unambiguously increase, with identical qualitative effect on  $z_1$  and  $z_2$ , for given  $z_0$ .

<sup>18</sup>Head and Ries (2002) investigate the influence of offshore production by Japanese multinationals on domestic skill intensity, using firm-level data. They find that additional foreign affiliate employment in low

firms and skill upgrading of workers induced by globalization unambiguously increase real domestic income,<sup>19</sup> and consequently the demand for the competitive good, requiring more labor in that sector:  $dz_0 > 0$  as relative wages rise in low-skill tasks and labor pours out of the intermediate  $M$ -tasks. Foreign income also benefits from expanding MN activities, increasing the demand for the country's exports. This contributes to raise even more the price of  $X$ , inducing domestic consumers to substitute in favor of the non-traded service occupations hence pushing  $z_0$  further to the right. The new equilibrium wage distribution is shown in Figure 7, and clearly displays job and wage polarization.

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income countries raises skill intensity at home, but that this effect falls as investment shifts towards high income countries. This is clearly consistent with vertical specialization, and provides evidence that vertical specialization by multinationals contributes to skill upgrading domestically. Hansson (2005) reaches similar conclusions on Swedish MNEs during the years 1990-97.

<sup>19</sup>See Jung and Mercenier (2008) for a formal demonstration.

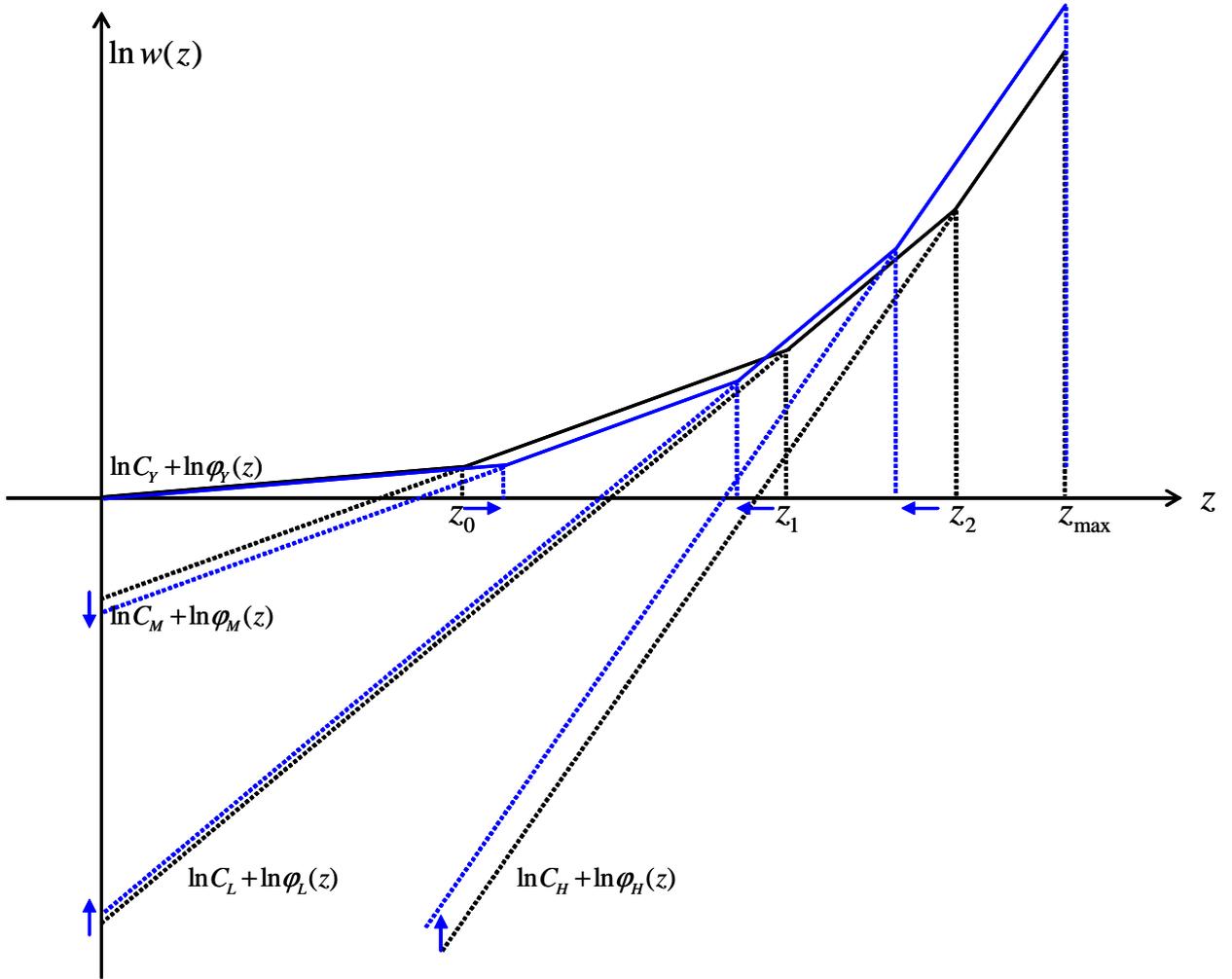


Figure 7: The effect of rising globalization on the equilibrium wage distribution.

RBTC and rising globalization can therefore have very similar effects, as one should presumably have expected. Our analysis highlights important qualitative differences between the two, however. A first difference is that job and wage polarization is the *only* possible equilibrium outcome of the globalization shock, whereas it is not for RBTC, as we have shown. The two shocks being simultaneous, they could yield opposite effects on the job and wage distributions, with globalization providing the strongest driving force. Though it is possible that in the future, as the relative intensity of these two forces change, empirical results will uncover such opposing effects, the evidence we have today seems to militate against such a possibility (see for instance Goos and Manning, 2007). We conclude that both shocks are equally likely to cause current labor market polarization.

A second important difference is that, with rising globalization, all workers that remain affected to performing  $M$ -tasks suffer a same proportional wage loss, independently of their skill level. The reason is that globalization acts as a demand-side shock on the production of these tasks by shifting leftward the global demand for these tasks; in contrast, RBTC acts as an internal transformation force that affects the way these tasks are being performed within each firm. This has two interesting implications. Firstly, globalization should be redrawing the average wage curve into a U-shape, which is not what the second stylized fact suggests. Secondly, a contraction of the 50-10 log-wage differential appears to be a robust consequence of the globalization shock<sup>20</sup> though it is only one among other possible outcomes of RBTC. In contrast, only RBTC induces wage inequalities to rise within the same repetitive task activities. This clearly suggests that the RBTC assumption is the only one that can generate effects consistent with the observation that overall and within-group wage inequalities are changing in a very disproportionate way, and for some measures even in opposite directions (stylized fact four). It seems therefore that globalization and the rise of offshore outsourcing cannot be the dominant driving force responsible for the recent transformations of labor markets (consistently with the empirical findings of Feenstra and Hanson (1999), among others).

## 6 A numerical illustration

### 6.1 The initial equilibrium

In this section, we illustrate our theoretical discussion with numerical simulations. To do this, we first set the stage by characterizing the initial equilibrium of this illustrative economy. Service occupations account for approximately 10% of U.S. national income, so we set  $\beta = 0.90$  for household preferences. We follow Krugman (1991) and choose  $\sigma = 4$  for the differentiation elasticity. We assume a uniform density distribution  $g(z)$  for skills. Consistently with our graphical representation in Figure 1, technologies are

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<sup>20</sup>Provided, of course, that non-routine low-skill jobs account for more than 10%, and non-repetitive cognitive jobs less than 50% of the labor force, as realism suggests.

assumed log-linear. We set:

$$\begin{aligned}\ln \varphi_Y(z) &\approx 0.930 * z \\ \ln \varphi_M(z) &= 1.10 * \ln \varphi_Y(z) \\ \ln \varphi_L(z) &\approx 1.435 * z \\ \ln \varphi_H(z) &= 1.10 * \ln \varphi_L(z).\end{aligned}$$

Empirical evidence on the level of the fixed costs is scarce but it is generally thought that the total fixed costs of a vertically fragmented firm is less than twice those of a domestic firm. We choose the following relative fixed costs:

$$\begin{aligned}F_L &= 1.00 \\ F_H + F_I &= 1.62\end{aligned}$$

The previous assumptions on the technologies imply a calibrated value of  $\theta \approx 0.90$ . The equilibrium skill thresholds are then chosen as:

$$\begin{aligned}z_{\min} &= 0.0 \\ z_0 &\approx 0.18 \\ z_1 &\approx 0.74 \\ z_2 &\approx 1.00 \\ z_{\max} &\approx 1.06\end{aligned}$$

With these parameter values, we are able to compute the initial equilibrium, characterized by the following employment shares, GNP shares, and relative wages (measured in efficiency units) by tasks:

	<i>Employment shares (%)</i>	<i>Value-added shares (%)</i>	<i>Relative wages (efficiency units)</i>
<i>Y</i>	16.9	10	1.000
<i>M</i>	52.9	46	.983
<i>L</i>	24.5	34	.725
<i>H</i>	5.7	10	.628

These shares are quite reasonable, and suggest that the values chosen for the parameters bear some realism.<sup>21</sup>

## 6.2 Comparing results from competing assumptions

Table 1 reports, for the four different shocks discussed in the text, the computed effects (as % deviations from initial equilibrium) on job shares and wages (the latter measured both in efficiency units and as averages per job) by type of tasks, as well as within-task wage Theil-inequality measures. The results are also graphed in Figures 8,9 and 10, as indices.

To get these numbers, the following shocks have been implemented: for RBTC, we multiply both  $\kappa_M$  and the slope of the productivity schedule  $\ln \varphi_M(z)$  by 2%; for SBTC we add to this a 4% increment to  $d \ln \varphi_Y(z)/dz$ ; to capture the effect of increasing globalization, we reduce  $F_I$  by 1%;<sup>22</sup> an ageing population is assumed to reduce its consumption share  $\beta$  by 2%. The size of these shocks is of course arbitrary and has been chosen so as to yield effects of approximately the same magnitudes: we have checked that none of the qualitative results depend on the amplitude of the shocks within the range consistent with an interior solution.

We check from these results that the only two driving forces that cause job and wage polarization are indeed RBTC and globalization. Nevertheless, the two have very different effects on average wages. The globalization-induced contraction of employment in routine tasks comes with a fall of the average wage which, as we already know from our theoretical analysis, need not be due to composition changes only: all workers that remain employed to perform those tasks see their wages fall in equal proportions so that within-task wage inequalities are reduced. With RBTC, in contrast, rising residual wage inequalities tend to counter –or to add-up to– skill composition changes in routine tasks.

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<sup>21</sup>The values of the parameters characterizing the different technologies were actually calibrated to reproduce approximately U.S. employment and GDP shares.

<sup>22</sup>As we know –and indeed have checked– reducing  $\theta$  has the same qualitative effects.

	<i>RBTC</i>	<i>SBTC</i>	<i>Ageing population</i>	<i>Globalization</i>
<b><i>Employment shares</i></b>				
<i>Y</i>	1.661	-2.281	4.040	0.260
<i>M</i>	-1.782	-0.136	-0.963	-2.583
<i>L</i>	1.622	1.748	-0.659	-1.134
<i>H</i>	4.629	0.518	-0.196	27.860
<i>L+H</i>	2.194	1.514	-0.571	4.380
<b><i>Wages (efficiency u.)</i></b>				
<i>C<sub>Y</sub></i>	0.000	0.000	0.000	0.000
<i>C<sub>M</sub></i>	-0.401	0.038	-0.068	-0.004
<i>C<sub>L</sub></i>	1.404	0.238	-0.143	0.574
<i>C<sub>H</sub></i>	1.445	0.242	-0.144	0.820
<b><i>Average wage per job</i></b>				
<i>Y</i>	0.143	-0.196	0.348	0.022
<i>M</i>	0.336	-0.424	0.372	-0.769
<i>L</i>	0.707	-0.114	-0.010	-1.657
<i>H</i>	1.223	0.218	-0.135	-0.500
<i>L+H</i>	0.940	-0.084	-0.021	-0.300
<b><i>Theil within-task wage inequality</i></b>				
<i>T<sub>Y</sub></i>	3.362	-4.502	8.241	0.532
<i>T<sub>M</sub></i>	0.356	-0.269	-1.906	-5.063
<i>T<sub>L</sub></i>	3.257	3.514	-1.306	-2.248
<i>T<sub>H</sub></i>	9.477	1.051	-0.392	63.490

Table 1: Computed effects of alternative shocks (% changes)

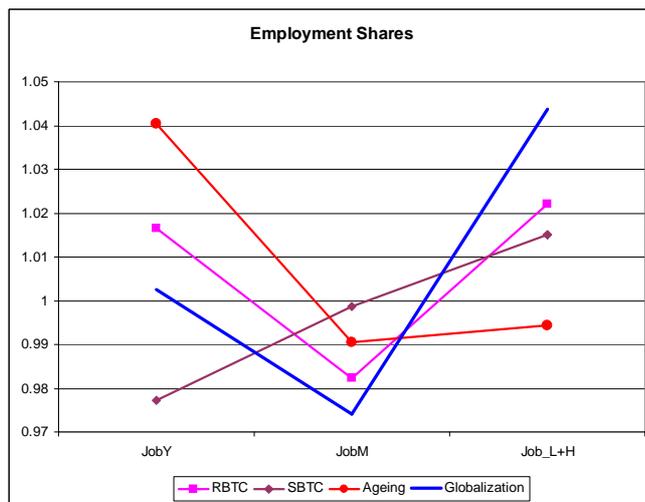


Figure 8: Effects of competing shocks on employment shares, indices.

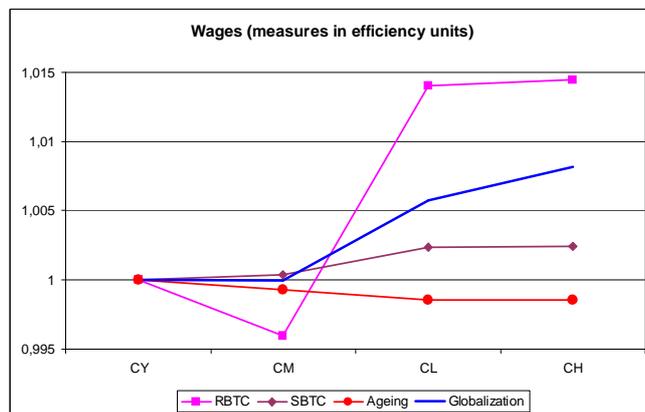


Figure 9: Effects of competing shocks on wages (measured in efficiency units), indices.

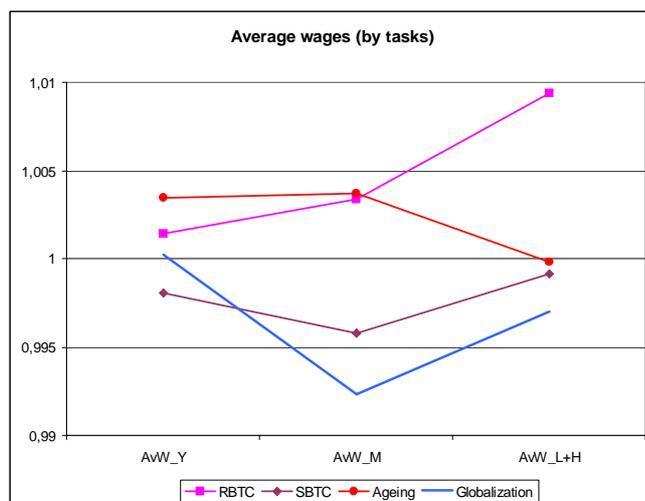


Figure 10: Effects of competing shocks on task average wages, indices.

## 7 Conclusion

Labor markets are undergoing important transformations since the early 90s. This has been extensively documented, and some stylized facts clearly emerge from a now abundant empirical literature. Various explanations have been proposed, and to some extent confronted with the data. We are not aware of any effort made to systematically explore the theoretical implications of these hypotheses –which are obviously general equilibrium– nor of tentative to rigorously evaluate their ability to fit the stylized facts. Our paper contributes to fill that gap.

We have developed a theoretical framework that is rich enough for the purpose at hand, yet actually very simple. The model has first been developed and explored in the context of a closed economy. We have investigated how well three of the main suggested explanations –namely RBTC, SBTC and demand shifts due to ageing and/or non homothetic preferences– do fit the empirical evidence. We show that only the first of these assumptions can account for the stylized facts. Key to this conclusion is our explicit modeling of workers’ ability to skill up/down-grade endogenously as they relocate themselves to different tasks because of changing comparative advantages.

The analysis has then been generalized to the open economy within a globalized world. To the endogenous skill up/down-grading of workers as they move to different tasks, globalization adds the possibility for firms to endogenously choose the geographic location –locally or offshore– of part of their production and, doing so, to technology up/down-grade their production technologies. We have shown that with this additional mechanism the conclusions on the role of technical progress in shaping labor markets could qualitatively be affected, though this does not seem to be empirically relevant, at least up to now. Not surprisingly, RBTC and rising globalization are shown to have very similar effects on the employment and wage (measured in efficiency units) distributions by tasks. But we are able to highlight more sophisticated potential differences between the two, in particular with respect to wage inequalities. We show that they are not equally likely to explain the observed slowing in the growth of overall wage inequality through between-group adjustments. Furthermore, according to our analysis, only RBTC could cause the

rise in residual inequality –i.e., inequalities among observationally equivalent workers–, a phenomenon well documented for which few convincing explanations are available. This is because globalization acts on the local production of intermediate repetitive tasks by shifting the global demand for these domestically-performed tasks to the left; in contrast, RBTC acts as a supply-side force that induces internal transformations of the way these tasks are being performed within each firm. Needless to say, this discriminating conclusion stems on our formalization of the two competing assumptions. Whether our implementation of these driving forces is or not realistic is of course an empirical question, but the assumption that the technical progress embodied in new equipments will boost the productivity of workers performing routine tasks can hardly be perceived as unlikely.

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