# Routinization-Biased Technical Change and Globalization: Understanding Labor Market Polarization

Jaewon Jung* and Jean Mercenier†

This version: January 2014‡

**Abstract**

There is now ample evidence that jobs and wages have been polarizing at the extremes of the skill distribution since the early 90s. Possible explanations include, among others, routinization-biased technical change (technical progress substituting more easily for labor in performing routine rather than non-routine tasks) and globalization (more specifically, offshore outsourcing by multinational firms). In this paper, we develop a unified theoretical general equilibrium model and examine the implications of each competing hypotheses for labor market polarization.

*Keywords:* Biased Technical Change, Offshore Outsourcing, Labor Market Polarization, Wage Inequality.

*JEL Classification:* J21, J23, J24, F66.

*Corresponding author. School of Business and Economics, RWTH Aachen University and THEMA, Université de Cergy-Pontoise, Templergraben 64, 52056 Aachen, Germany. Tel.: +49-(0)241-80-93339; fax: +49-(0)241-80-92393; e-mail: Jung@wiwi.rwth-aachen.de.

†Université Panthéon-Assas (U. Paris 2), 92 Rue Assas, 75006 Paris, France. Tel.: +33-(0)1-4441-5839; e-mail: Jean.Mercenier@u-paris2.fr.

‡A previous version of this paper was presented at various conferences, workshops and seminars, including the Royal Economic Society Conference 2011, and the Canadian Economic Association Meeting 2011, under the title: "Routinization-Biased Technical Change, Globalization and Labor Market Polarization: Does Theory Fit the Facts"; we thank participants for comments. We are also grateful to Matias Cortes, Nicole Fortin, Maarten Goos, Thomas Lemieux and Gerald Willmann for helpful comments and/or encouragements. We finally wish to thank Bruce A. Blonigen, Co-editor, and two anonymous referees for suggestions that helped improve the manuscript. Any remaining shortcomings are of course ours. The paper was partly written while the second author was visiting the Fundação Getulio Vargas (Rio de Janeiro) thanks to financial support from INCT-CNPq and Faperj.

# 1 Introduction

Until recently, the most widely accepted explanation for the spectacular rise of wage inequalities since the late 70s was built on the role of technical progress being biased in favor of skilled labor.[1] Important transformations of labor markets since the early 90s have, however, induced questioning of this skill-biased technical-change (SBTC). Employment has clearly been polarizing in favor of both high- and low-skill jobs, as shown by Autor, Katz and Kearney (2006) for the U.S.; Goos and Manning (2007) for the U.K.; Spitz-Oener (2006) and Dustmann, Ludsteck and Schönberg (2009) for Germany; Ikenaga and Kambayashi (2010) for Japan; and Goos, Manning, and Salomons (2009) for other European economies, among others.[2] Wages have simultaneously been polarizing in the U.S., as also shown by Autor, Katz and Kearney (2006).[3] These empirical developments are clearly inconsistent with the SBTC assumption; furthermore, they cannot be understood using the standard neoclassical two-skill growth model: see Acemoglu and Autor (2011) for an exposition of the inconsistencies between this "canonical" model's predictions and the recent empirical facts.

In a recent influential paper, Autor, Levy and Murnane (2003) have advocated for –and, using U.S. data, provided evidence in favor of– a reinterpretation of the role of technical progress in shaping labor markets: technology –and computers in particular– can replace labor in "routine" tasks (those tasks that involve step-by-step procedures and can therefore be codified) but not in "non-routine" tasks, hence inducing what we shall refer to as routinization-biased technical-change (RBTC hereafter). The fact that these routine tasks tend to be concentrated in the middle of the skill distribution (Goos and Manning, 2007), offers considerable support in favor of this explanation. The novelty of this theory on the effects of technical progress comes clearly from its shift of emphasis from workers' skills to the type of tasks performed: it is the returns to specific tasks,

[1] See Katz and Autor (1999) for a survey of this literature, and Acemoglu and Autor (2011) for a recent reappraisal.

[2] Interestingly, Cortes (2012) shows, using U.S. data, that rates of exit of individuals from routine manual jobs are low and quite stable in time, which suggests that polarization of employment is due to a large extent to reduced entry into these occupations. In our static framework, we do not distinguish between entry and exit, but only model net flows.

[3] There is yet unclear evidence of wage polarization in Europe, however; whether this is due to the fact that labor markets are less competitive in these countries is yet an open question.

rather than to specific skills, that are being depressed by the emergence of computer and information technologies. And indeed, as shown by Acemoglu and Autor (2011), changes in inter-occupation wage differentials constitute an important explanatory factor to the growth in the variance of U.S. wages since the early 80s.

There are other possible explanations to these facts, however. Indeed, changes in international trade also provide a potentially important cause of labor market transformations. Until recently, a consensus seemed to exist among most economists that trade was less important than technological change in explaining wage inequalities. But this view is increasingly being questioned both theoretically and empirically.[4] Early work by Feenstra and Hanson (1999) emphasized that, to capture the role of international trade on the wage distribution, attention should be shifted from trade in final goods to trade in intermediate inputs. More recently, with the widespread adoption of offshoring strategies by multinational enterprises, economists have increasingly shifted their attention to the effects of this new form of trade: see Grossman and Rossi-Hansberg (2008) for a theoretical trade model for tasks, and Blinder (2009) for a quantitative appraisal of the potential labor displacement consequences of offshoring practices by U.S. firms. To understand the potential role of offshoring in carving labor markets, and contrast it to that of technical change, we therefore need a theoretical model that explicitly links the behavior of multinational firms to the wage and employment distributions.

Finally, demand side factors, such as composition shifts due to population ageing and/or non-homothetic preferences have also been suggested as potential explanations for recent labor market transformations: see e.g., Manning (2004). Though empirical investigations have yet given little support for this hypothesis, the ongoing steady expansion of employment in service occupations (Autor and Dorn, 2009) suggest that it could play a more important role in the future. It is therefore also useful to understand in which way this force is likely to affect the employment and wage distributions.

Our aim in this paper is to highlight the likely implications of each of these competing hypotheses within a unified theoretical general equilibrium framework. For this, we propose a structural model, parsimonious enough to be tractable, yet rich enough so that

[4]As an illustration of the former, see Helpman, Itskhoki, Muendler and Redding (2012); of the latter, see Ebenstein, Harrison, McMillan and Phillips (2009).

the full implications of these driving forces can be assessed and compared. Our analysis will in particular highlight how the presence of multinationals could render ambiguous the effects of RBTC on the wage distribution. We shall also argue that, even when apparently very similar, the qualitative effects of RBTC and rising globalization could differ enough to be potentially identifiable empirically.

We first develop a multi-task based two-sector closed-economy general equilibrium model with explicit distinction between labor skills and tasks. Labor supply is in the form of a fixed distribution over a continuum of skills; therefore 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 therefore account for labor movements in and out of occupation types, and are able to assess the effects of these employment changes on equilibrium wages, as workers task up-grade or task down-grade.[5] The framework is also fit to highlight within-task endogenous composition effects, with individual wage changes being contrasted with average wage changes, and between-task inequality adjustments distinguished from within-task 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, with little additional work, we open our economy to trade. In this open economy equilibrium, two types of firms coexist with different cost structures: the multinational firms that offshore the production of some tasks, and the domestic-only firms that produce all of their inputs locally. We show how, because of the presence of multinational firms, labor markets in this open economy may react very differently to RBTC. We then acknowledge the possibility for firms to respond to changes in opportunities due to rising globalization by endogenously choosing whether or not to turn multinational and offshore outsource the production of some of their intermediate input tasks to cheap labor countries. This makes it possible to explore the role of rising globalization in shaping today's labor markets, and

[5] Kambourov and Manovskii (2008) and Moscarini and Thomsson (2007), among others, document the importance of occupational mobility in the US.

to compare this, in a single consistent set-up, to other potential causes. The model is adapted from Jung and Mercenier (2008), itself firmly rooted in Yeaple (2005).

Some theoretical efforts have already been made to rationalize recent labor market transformations based on a clear distinction between skills and tasks. However, only a few general equilibrium set-ups are available that highlight how, based on worker's comparative advantages, the wage and employment distributions are endogenously carved by the reallocation of skills to tasks following changes in technology or trade. Most closely related to our paper, are the works of Acemoglu and Autor (2011) and of Costinot and Vogel (2010). The first authors develop a Ricardian model in which an exogenously fixed stock of three different skill types (low, middle and high) are endogenously allocated to a continuum of tasks; doing so, they critically impose the law of one price to hold within each skill category, so that wages are equalized across occupations, conditional on skill. This assumption is strongly at odds with empirical evidence (see, e.g., Heckman and Scheinkman, 1987, and Gibbons, Katz, Lemieux and Parent, 2005). Furthermore, it gives the counter-intuitive prediction that all workers crowded out of routine tasks by machines, will experience the same wage change regardless of whether they are task-downgraded or task-upgraded.[6] In contrast, we allow wages to vary across occupations, conditional on skills, consistently with a Roy-like assignment model of the wage determination (thus, offering what we believe is a tractable theoretical general equilibrium version of the partial equilibrium set-up adopted by Firpo, Fortin and Lemieux, 2011, in their detailed econometric investigation).[7] Also, Acemoglu and Autor (2011) heavily rely on the restriction that tasks enter symmetrically as intermediate inputs into the production of a single final good, so that their ability to capture the evolution of the demand for services during the past several decades is limited. We avoid this limitation by adopting a richer representation of product markets. Finally, in their model, the effects of new technologies and offshoring are captured identically by an exogenous drop in the price of the same tasks. We, in contrast, offer a more sophisticated structural representation of the two different exogenous shocks, and argue that potentially different effects on labor markets may follow.

[6] See Cortes (2012) for evidence against such prediction.

[7] Recent empirical works highlight that an important component of human capital is occupation- and task-specific. See among others, Kambourov and Manovskii (2009), Gathmann and Schönberg (2010) and Poletaev and Robinson (2008).

In their impressive paper, Costinot and Vogel (2010) also develop a Roy-like assignment model in which an exogenously given labor supply distributed over a continuum of workers (or skills) is allocated across a continuum of goods (or tasks) based on a very general log-supermodularity assumption of workers' comparative advantages. They offer sufficient conditions for robust monotone comparative static predictions, and illustrate how their methodology can be applied to shed light on the consequences of technical change and trade in tasks. Their approach, however, crucially depends on technologies being characterized by constant returns to scale and perfectly competitive production markets, thereby with limited insights on globalization induced competition between domestic firms and multinationals and the induced effects on wages and employment. Also, their continuum-by-continuum matching framework does not allow to study the effects of offshoring some specific tasks: they interpret offshoring as an increase of productivity of all foreign workers, which finally leads to a counter-intuitive result that offshoring induces only task-upgrading of workers in both countries.[8] We, in contrast, explicitly model the behavior of firms endogenously choosing to offshore the production of some tasks as a result of a changing domestic and international environment. We therefore offer a richer description of the interaction between technical progress and international trade in tasks, and uncover reasons that may explain why the contribution of technical progress and offshoring in shaping today's labor markets are so difficult to disentangle empirically. Finally, because of the high degree of abstraction they adopt in their formalization, their analysis is unlikely to bring much help to empirical investigators in interpreting their findings. In contrast, our theoretical model is cast in terms that can readily be used by applied researchers, as Cortes (2012) amply proves.

The paper is organized as follows. In the next section, the core structure of our model is laid down. Using this simplified closed economy setting, we explore in Section 3 the effects

[8] Though the focus is different, a recent work by Blanchard and Willmann (2013) builds a similar continuum-by-continuum matching framework and predicts the opposite. In theirs, opening up to trade with a country having a comparative advantage in middling tasks induces a non-monotonic occupational mobility –a simultaneous sorting-up and -down of workers– in both home and foreign countries. Such non-monotonic occupational changes are supported by empirical investigations. For instance, using Danish panel data, Groes, Kircher and Manovskii (2010), find a clear U-shaped pattern for occupational mobility: occupational switching probabilities are particularly high for workers at the extremes of the wage distribution within an occupation. Also, they highlight that within an occupation the lowest wage workers tend to leave for even lower wage paying occupations, while the highest wage earners tend to switch for even higher paying occupations, which implies both task down-grading and up-grading at the extremes.

of RBTC and show under which conditions it can indeed rationalize most of the recent empirical findings; we also show in this section why SBTC and the demand-composition shift hypothesis fail to account for the stylized facts. In Section 4, 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 conclude in Section 5. An appendix reports some numerical simulations that confirm and supplement our theoretical discussion.

# 2 The closed economy model

## 2.1 Households

Households have Cobb-Douglas preferences combining two final goods, $X$ and $Y$. Industry $X$ supplies a Dixit-Stiglitz aggregate of differentiated products, whereas goods from industry $Y$ are homogeneous. We write:

$$Con = \beta \ln X + (1-\beta)\ln Y, \qquad 0<\beta<1 \tag{1}$$

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

where $Con$ stands for aggregate utility and $\beta$ is the Cobb-Douglas expenditure share parameter; $N$ represents the mass of available $X$ varieties; $x^d(i)$ denotes consumption demand for each variety $i$ and $\sigma = 1/(1-\rho)$ is a constant substitution elasticity between varieties.[9] Maximizing utility subject to income ($Inc$) immediately yields the demands for

[9] In our closed economy setting, treating $X$ as a homogeneous competitively produced good would not qualitatively affect the 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 introducing 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.

final goods:

$$
\begin{aligned}
x^d(i) &= \left(\frac{P_X}{p(i)}\right)^{\sigma} \frac{\beta Inc}{P_X} && (3) \\
P_X &= \left[\int_{i \in N} p(i)^{1-\sigma} di\right]^{\frac{1}{1-\sigma}} && (4) \\
p_Y Y &= (1-\beta) Inc. && (5)
\end{aligned}
$$

where $p_Y$ and $p(i)$ are the market prices respectively of $Y$ and variety $i$, and $P_X$ is the price index of the aggregate bundle $X$.

Households also supply labor. There is a continuum of workers differentiated by their skills, which we shall characterize by the single-dimensional index $z$. We focus in this paper on the endogenous assignment of workers to occupations, and assume given the cumulative distribution $G(z)$ on support $[z_{\min}, z_{\max}]$. We shall refer to $z$ indifferently as the worker's skill, or talent or ability.[10] Finally, households own an exogenous stock of capital.

### 2.2 Firms and the labor market

Production of $Y$ requires execution of tasks that by nature cannot be routinized into step by step procedures, yet is not very demanding in terms of skills: these are typically non-routine manual tasks, mostly associated with service occupations (taxi driving, cleaning, home health caring, etc.)[11] Producing $Y$ therefore only requires labor, and all workers are perfect substitutes in this production activity, though not with equal productivity: the marginal product of workers performing such tasks is an increasing function of their abilities $z$: $\varphi_Y(z) > 0$ with $\frac{d\varphi_Y(z)}{dz} > 0$. Though we shall refer to this function as the technology for producing the non-routine manual tasks, it should however be understood as reflecting not only the specific ability of individuals, but also the efficient assignment of

[10] Abstracting from changing education, gender composition and experience indeed makes sense in this context: Acemoglu and Autor (2011) write that "this polarization of employment does not merely reflect a change in the composition of skills available in the labor market but also a change in the allocation of skill groups across occupations— and, in fact, the explanatory power of occupation in accounting for wage differences across workers has significantly increased over time". See Blanchard and Willmann (2013) for an effort to endogenize this skill distribution through investment decisions in education by individuals.

[11] 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).

workers across occupations within this task aggregate.[12] Service occupations are produced perfectly competitively so that marginal-cost pricing holds and $p_Y = C_Y$, where $C_Y$ is the marginal production cost, which we choose to be the numeraire. Observe that $C_Y$ is also the measured-in-efficiency-units wage earned by workers who perform these tasks.

In the $X$ industry, there is a set of firms, each supplying a single differentiated variety $i$ in amount $x(i)$. We assume symmetry to prevail between these firms, so that $x = x(i)$, and we hereafter drop the variety argument $i$ when no confusion arises.[13] These final goods are substantially more sophisticated than those from the other industry, so that the production of each variety involves a fixed cost in addition to combining two types of intermediate variable inputs, respectively in amount $l$ and $m$. The first input, which we shall refer to as the non-repetitive cognitive-task input, is the aggregate output of occupations mostly associated –though not exclusively– with white-collar headquarter services. Because the production that requires these tasks is not easily routinizable, we shall assume that it cannot be performed by machines but exclusively by workers.[14] All workers are perfect substitutes in performing these tasks but differ in their productivity; individual abilities (and efficient assignment of workers to different occupations within this input aggregate on the basis of abilities) make the production technology for performing these non-repetitive cognitive tasks increasing in $z$: $\varphi_L(z) > 0$ with $\frac{d\varphi_L(z)}{dz} > 0$. The second intermediate input, produced in amount $m$ within a firm, results from all occupations that are repetitive by nature, be they manual or cognitive; these include most blue-collar occupations but also a significant subset of occupations performed by white collar workers such as bookkeeping.[15] Here again we assume that all workers are perfect substitutes in performing these tasks, but that labor productivity rises with $z$: $\varphi_M(z) > 0$ with $\frac{d\varphi_M(z)}{dz} > 0$. However, because these occupations are routinizable by nature, they can be performed almost equally well by machines: we simplify by making the assumption that capital and labor enter as

[12] See e.g., Groes, Kircher and Manovskii (2010) and Cortes (2012) for evidence of selection on ability in occupational transitions.

[13] The symmetry assumption implies identical technology and scale.

[14] We could alternatively assume that labor and capital enter complementarily in the production of these tasks but this would only change the presentation, not the predictions of the model. Assuming weak substitutability rather than complementarity would of course weaken the results making them dependent on the value of the substitution elasticity between labor and capital.

[15] These correspond to the *routine manual* and the *routine cognitive* tasks defined in Acemoglu and Autor (2011).

perfect substitutes in the production of this intermediate input.[16] We next assume (as is quite common in this type of literature) perfect complementarity between white-collar headquarter services and blue-collar production; hence, the two intermediate inputs are combined into a final variety using a Leontief technology; conveniently choosing units, we have for each firm $i$:

$$x = l = m. \tag{6}$$

Observe that our characterization of technologies ensures ($a$) that the marginal costs of these intermediate tasks –which we shall denote respectively $C_L$ and $C_M$– are also the prevailing measured-in-efficiency-units wages; ($b$) that $(C_M + C_L)$ is the marginal production cost of a variety $i$. Without loss of generality, we conveniently express that the fixed costs take the form of forgone output with value $(C_M + C_L)F$.

In equilibrium, an individual worker's productivity will reflect both its skills and the specific occupation he performs. We know that a high-$z$ worker is absolutely more productive than a low-$z$ worker if both are producing the same task. We now make the additional assumption that workers with higher $z$ are relatively more efficient when producing more sophisticated tasks. Formally, we impose that

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

with $\varphi_Y(z_{\min}) = \varphi_M(z_{\min}) = \varphi_L(z_{\min}) = 1$.[17] This means that the most skilled workers have a comparative advantage in non-repetitive cognitive occupations, and the least skilled workers a comparative advantage in performing non-repetitive non-cognitive tasks. In equilibrium, assuming labor markets are competitive, workers will endogenously sort between the three types of occupations according to their respective comparative advantages.[18] Let $z_0$ and $z_1$ be equilibrium skill thresholds with $z_{\min} < z_0 < z_1 < z_{\max}$. Then,

[16] Obviously, assuming capital and labor are highly –rather than perfectly– substitutable would only make the results dependent on the value of the substitution elasticity without otherwise affecting the qualitative predictions of the model.

[17] This assumption, in our model, is equivalent to imposing strict log-supermodularity in more general frameworks as in Costinot and Vogel (2010).

[18] Assuming perfectly competitive labor markets in Europe is obviously an oversimplification because of, among other things, the role of trade unions in wage setting negotiations. This is presumably why wage polarization does not come out significantly in most European studies despite clear employment polarization. There is, however, evidence that the bargaining power of trade unions has decreased substantially. For an empirical analysis of the interaction between labor and product market imperfections related to

the least skilled workers, those with $z \in [z_{\min}, z_0)$, will be employed in service occupations, those with talents $z \in [z_0, z_1)$ will be hired in repetitive occupations, and the most talented, those with $z \in [z_1, z_{\max}]$ will allocate themselves to performing non-repetitive cognitive tasks.[19] Figure 1 summarizes these assumptions for the particular case of log-linear functional forms, which we shall hereafter assume for ease of exposition.[20]

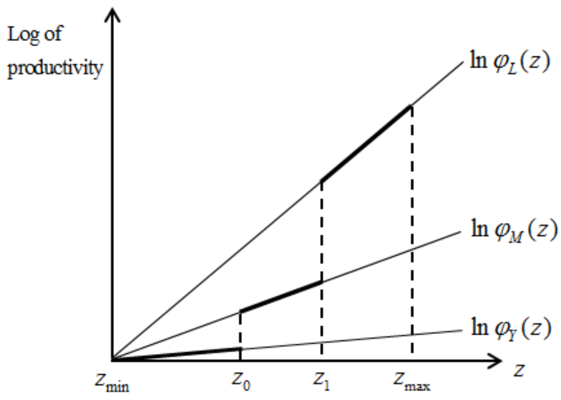


Figure 1: The task specific skill productivity schedules.

Workers are paid their marginal product, so that the equilibrium wage distribution satisfies:

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

Individuals with skills $z_0$ and $z_1$ should have, in equilibrium, no incentive to relocate to other tasks, so that two no-arbitrage conditions will tie together the wages $C_j$, $j \in$

globalization, see Abraham, Konings and Vanormelingen (2009). Though their analysis focusses on the effects of globalization rather than of technical change, their conclusions clearly suggest that these labor market imperfections are not crucial for our purpose. Wagner (2011) in his careful empirical investigation of German manufacturing enterprises' data, finds similar evidence.

[19] Gibbons, Katz, Lemieux and Parent (2005) also develop a model in which workers sort according to their comparative advantage, and their econometric results confirm a systematic allocation of high skilled to highly paid occupations.

[20] More general functional forms, consistent with our assumptions, could of course be adopted, but that would drastically complicate the exposition with no additional insight gained.

$\{Y, M, L\}$:

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

With $C_Y$ set to unity by arbitrary choice of a numeraire, these two indifference conditions fix the wages in repetitive and non-repetitive cognitive tasks:

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

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

Note from (7) that $C_Y > C_M > C_L$ and that $C_M$ and $C_L$ are decreasing respectively in $z_0$ and $z_1$. With log-linear skill-productivity schedules, the equilibrium wage distribution is as illustrated in Figure 2. This equilibrium wage distribution is entirely consistent with the empirical evidence reported by Cortes (2012) for the U.S.; he, in addition, shows that it is not qualitatively driven by the composition of the workforce across occupations along observable characteristics.[21]

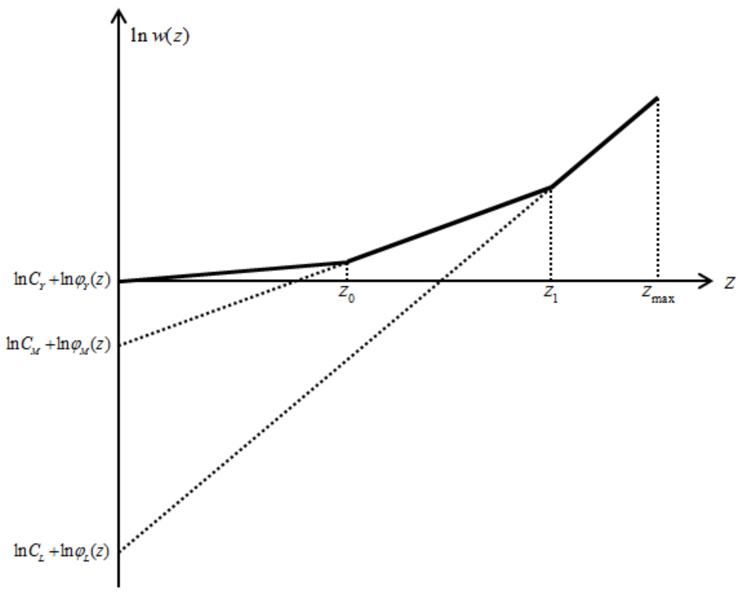


Figure 2: The equilibrium wage distribution with log-linear task productivity schedules.

[21] He notes that even after taking out the effects of all observable characteristics, non-routine cognitive jobs are high paying jobs, routine jobs are in the middle of the distribution, and non-routine manual jobs are low paying jobs.

Marginal-cost pricing is clearly non sustainable in the $X$ industry. We shall assume monopolistic competition to prevail between the firms producing the differentiated varieties $i$; hence, with the Dixit-Stiglitz preferences (2), each producer will charge a constant mark-up rate; the symmetry assumption then ensures that all varieties will have equal prices $p = p(i)$, $i \in N$, with

$$p = \frac{\sigma}{\sigma - 1} \left( C_L + C_M \right). \tag{12}$$

### 2.3 Equilibrium

The output associated with non-routine non-cognitive input tasks is in amount required to satisfy the demand (5) for service occupations:

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

In the $X$ industry, each firm's output meets the demand (3) for its own variety, so that

$$x = x^d(i), \ i \in N \ ; \tag{14}$$

it then follows, from the technology (6) and our characterization of fixed costs, that the aggregate production associated with non-routine cognitive tasks is in amount

$$\int_{z_1}^{z_{\max}} \varphi_L(z) dG(z) = N \left( x + F \right) \ ; \tag{15}$$

finally, the balance of inputs within $X$ firms requires that

$$\kappa_M \int_{z_0}^{z_1} \varphi_M(z) dG(z) = \int_{z_1}^{z_{\max}} \varphi_L(z) dG(z) \tag{16}$$

where the scaling factor $\kappa_M > 1$ accounts for the contribution of capital.[22] Observe that these equilibrium conditions for goods implicitly ensure that factor markets balance.

Because of free entry/exit of firms, no extra-normal profits can exist in equilibrium:

[22] Remember that capital is in exogenously fixed supply, and enters as a perfect substitute to labor in performing repetitive tasks, which makes this formulation legitimate, and convenient.

mark-up revenues exactly cover fixed production costs and $N$ adjusts therefore to ensure

$$\frac{1}{\sigma}px = (C_L + C_M)F \tag{17}$$

so that the individual firm's output is constant and proportional to $F$.[23]

Income then follows from full factor employment:

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

which completes the description of the model. The convexity of the wage distribution ensures that an equilibrium exists for this economy, and that it is unique.

# 3 Routinization-biased technical change (RBTC)

## 3.1 Formalizing the assumption

Autor, Levy and Murnane's (2003) hypothesis that new capital replaces increasingly well labor in routine tasks is readily implemented by shifting positively the parameter $\kappa_M$ in (16).

We believe, however, that doing so, we are likely to only capture the first-order effects on labor markets of new computer-based technologies. Indeed, there is a large literature in management (see, e.g., Mendelson, 2000) that highlights a second complementary channel through which new technologies affect labor markets: investments in computer-based information technologies induces adoption of organizational changes and new human resource practices (such as team works, shop floor meetings for information sharing etc.) that contribute to increase the productivity of production workers.[24] Furthermore, even though admittedly this literature does not explicitly distinguish between efficiency gains due to workers being task-upgraded from those due to workers performing identical tasks

[23] With fixed costs expressed as forgone output, zero extra-normal profits require that $px = (C_L + C_M)(x + F)$; making use of (12) immediately yields (17). Making again use of (12) to substitute out prices from (17) yields $x = (\sigma - 1)F$ : changes in the industry market-size will therefore only affect the number of varieties without inducing within firm adjustments, which eases interpretation of results.

[24] In their careful case investigation, Bartel, Ichniowski and Shaw (2007) write: "New IT-based production machinery is associated with an improvement in the efficiency of the stage of production in which it is involved. It does not improve the efficiency of phases of machining in which it is not involved", (p.1743).

more efficiently, it nevertheless suggests that within the same type of occupations, due to different absorptive capacity of workers with new technology arrivals, efficiency gains have been disproportionately associated with more highly skilled. Thus, technical progress would also induce a steeper skill-productivity schedule in repetitive occupations: in our set-up, an exogenous increase of the slope of $\ln \varphi_M(z)$. Though in practice, this is likely to have second order effects on the employment and wage distributions, we believe that it bears some importance because it captures a qualitative difference between RBTC and globalization. As we shall later argue, globalization acts on the local volume of intermediate repetitive tasks performed by reducing the global demand for this intermediate input (and therefore without affecting the slope of the skill-productivity schedule); in contrast, computerization acts as a supply-side force that induces internal transformations of the way these tasks are being produced within each firm.

Note that whether or not RBTC affects the steepness of the productivity schedule (in addition to increasing $\kappa_M$) does not affect the sign of its impact on the country's income $Inc$, which will unambiguously be positive (see (18)).

### 3.2 Labor market effects of RBTC

To understand how RBTC will affect the equilibrium wage distribution in Figure 2, it is convenient to proceed in two steps, and first consider, the effects of a steeper productivity schedule $\ln \varphi_M(z)$ alone. We focus on how the equilibrium skill thresholds $z_0$ and $z_1$ are being displaced. 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: $\Delta \ln C_L = \Delta \ln \varphi_M(\overline{z_1}) > 0$ from (9). From (16), however, it is apparent that, for $z_0$ given, $z_1$ will be pushed left so that the balance between input tasks within the $X$ industry can be restored: the relative demand for non-repetitive cognitive tasks rises inducing $X$ firms to task-upgrade the best among initial routine task workers, who therefore earn better wages; so do too the other non-routine cognitive-task workers as $C_L$ is pushed further up by a pure general equilibrium effect. Consider now what would result from new computerized investment flows: for given $z_0$, more abundant capital services ($d\kappa_M > 0$) will contribute to reduce the demand for workers in routine tasks by depressing their wages; most talented $M$ workers move into non-routine cognitive occupations, hence contributing to restore the balance between intermediate inputs in the $X$ industry: $z_1$ is shifted to the left with relative wages of all workers in non-repetitive high-skill intensive tasks rising. At this stage, it should be clear that both employment and wages (measured in efficiency units) have risen in non-routine cognitive tasks $L$ and have fallen in repetitive tasks $M$. $z_0$, however, is not an equilibrium skill-threshold: the $Y$ good is obviously now in relative scarce supply, so that its price has to rise (that is, $C_M$ and $C_L$ will fall in equal proportion relative to the numeraire $C_Y$), making it possible for producers in the $Y$ industry to offer better relative wages and attract the least-skilled workers out of repetitive intermediate tasks: the threshold $z_0$ is being pushed to the right as these workers task-downgrade. (Remember that the supply shock affects positively income, and therefore $Y$ because of (5)) The expansion of service occupations will tend to mitigate –but not reverse– the initial leftward shift of $z_1$.[25] Figure 3 displays how the equilibrium wage distribution has been affected. Cortes (2012) provides clear evidence that the mechanism just described is consistent with transformations experienced by the U.S. labor market in recent years. More specifically, he shows that there is a two-way labor movement out of routine jobs, with some workers up-grading to more cognitive tasks, and others down-grading to less repetitive non-cognitive occupations; the former are likely to experience (modest) real (as well as residual) wage increases, whereas the latter are likely to experience (large) wage cuts. Groes, Kircher and Manovskii (2010) identify similar two-way labor movements out of routine tasks using Danish data.

[25] More formally, we know that $\frac{dInc}{d\kappa_M} > 0$; we also know from (5) and (13) that $(1-\beta)Inc = \int_{z_{\min}}^{z_0} \varphi_Y(z)dG(z)$ and from (10), (11) and (16) that $\beta Inc = \frac{\varphi_Y(z_0)}{\varphi_M(z_0)}\left(1+\frac{\varphi_M(z_1)}{\varphi_L(z_1)}\right)\int_{z_1}^{z_{\max}} \varphi_L(z)dG(z)$. Therefore, the rise of $Inc$ due to RBTC implies $dz_0 > 0$ and $dz_1 < 0$. Here, the assumption of Cobb-Douglas preferences is of course crucial (with Cobb-Douglas preferences, expenditure shares are constant; with $p_Y$ fixed, the output volume $Y$ necessarily rises with income). The qualitative result would nevertheless hold provided that the substitution elasticity in consumption between the two final goods is not too high. Assuming a positive change of $\ln\varphi_M(z)$ alone would not affect the sign of $dz_0$, given that $\frac{dInc}{d\ln\varphi_M(z)} > 0$; its impact on $z_1$ would in that case be ambiguous, however, depending on the relative slopes of the productivity schedules of the $M$ and $L$ tasks. It is however clear that the latter effects are second order, and would therefore only mitigate those of $d\kappa_M$.

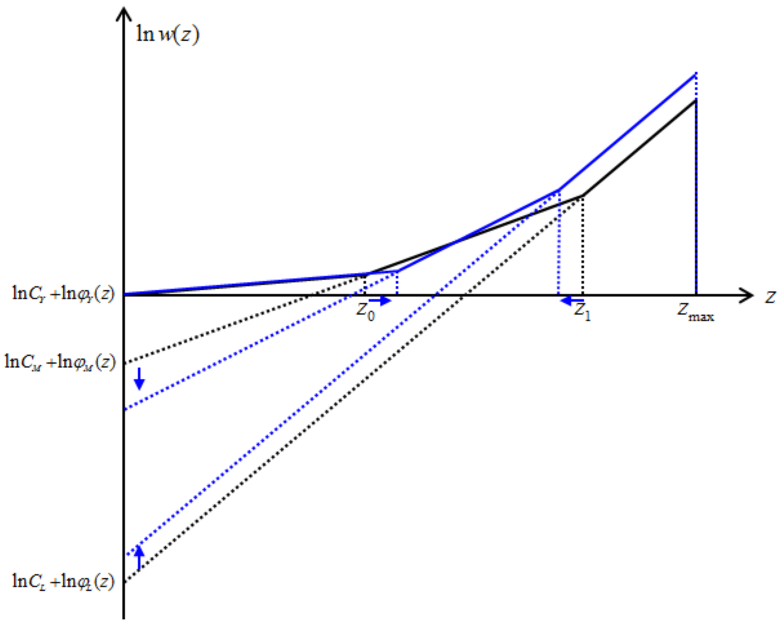


Figure 3: The effects of RBTC on the equilibrium wage distribution.

Observe that 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 (measured in efficiency units) have also unambiguously polarized, with $\Delta \ln C_L > \Delta \ln C_Y = 0 > \Delta \ln C_M$.[26]

Note also that the model does not only deliver interesting predictions on employment and wage (measured in efficiency units) changes, but also on composition effects and average wages within task aggregates. Indeed, with $z_0$ being shifted to the right, the average wage will unambiguously rise in service occupations (even though individual

[26]It should be mentioned that if $d\ln\varphi_M(z) > 0$ induces wage polarization unambiguously, $d\kappa_M > 0$ does not: given that $\frac{dz_0}{d\kappa_M} > 0$ and $\frac{dz_1}{d\kappa_M} < 0$, we have from (7), (10) and (11) that: $\frac{dC_Y}{d\kappa_M} = 0$, $\frac{dC_M}{d\kappa_M} < 0$ and $\frac{d\left(\frac{C_L}{C_M}\right)}{d\kappa_M} > 0$; however, the sign of $\frac{dC_L}{d\kappa_M}$ is analytically ambiguous and depends on the technological gap between $\varphi_Y(z)$, $\varphi_M(z)$ and $\varphi_L(z)$. Indeed, from (10) and (11), $\frac{d\ln C_L}{d\kappa_M} = \frac{d\ln\left(\frac{\varphi_Y(z_0)}{\varphi_M(z_0)}\right)}{dz_0}\frac{dz_0}{d\kappa_M} + \frac{d\ln\left(\frac{\varphi_M(z_1)}{\varphi_L(z_1)}\right)}{dz_1}\frac{dz_1}{d\kappa_M}$, where the first term is negative and the second positive. Thus, $\frac{d\ln C_L}{d\kappa_M}$ will be $> 0$ only if the technological gap between $M$ and $L$ is not too small relative to that between $Y$ and $M$. To see this, contrast the two extreme cases: with $0 < \frac{d\ln\varphi_Y(z)}{dz} < \frac{d\ln\varphi_M(z)}{dz} = \frac{d\ln\varphi_L(z)}{dz}$, it follows that $\frac{dC_M}{d\kappa_M} = \frac{dC_L}{d\kappa_M} < 0$; whereas with $0 < \frac{d\ln\varphi_Y(z)}{dz} = \frac{d\ln\varphi_M(z)}{dz} < \frac{d\ln\varphi_L(z)}{dz}$, we have $\frac{dC_M}{d\kappa_M} = 0 < \frac{dC_L}{d\kappa_M}$. Empirical evidence does not seem to be consistent with the predictions of the model in the former case.

workers who task-downgrade will unambiguously experience wage losses). This is because they have better skill endowments than those previously engaged in performing those tasks and therefore contribute positively to the average wage in these occupations. 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 non-repetitive cognitive jobs, those newly hired to perform such tasks are less talented. The same ambiguity prevails in repetitive occupations because some workers move out of these activities by task-upgrading and some by task-downgrading, and these workers are respectively the most- and the least- talented originally employed to perform these tasks. This highlights the difficulty of associating technical change to average labor productivity growth even when working with task-level disaggregation: the only tasks here that display unambiguous average labor productivity gains experience no technical change, even though individual workers here earn either unchanged or lower wages than before.

Observe that RBTC generates changes in wage inequalities that are broadly consistent with observed recent trends reported by Autor, Katz 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.[27] More remarkable is the prediction that wage inequalities unambiguously rise among observationally equivalent workers performing identical tasks.[28] Our model therefore offers an explanation for the well documented fact that overall and within-group wage inequality 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

[27] 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.

[28] Relative wage ratio among the workers who remain allocated to routine tasks rises unambiguously in favor of more skilled. However, applying a commonly used inequality measure in empirical studies (e.g., simple 90-10 log wage differentials) could lead to an ambiguous result because of the ambiguous composition effects, which would depend on the extent of compression in the range of skills of workers in the routine tasks.

One might wonder here if it would not be possible that variations of $z_0$ and $z_1$ are large enough so that all routine workers experience a wage fall. For this consider again the two extreme cases: with $0 < \frac{d\ln\varphi_Y(z)}{dz} = \frac{d\ln\varphi_M(z)}{dz} < \frac{d\ln\varphi_L(z)}{dz}$, $d\ln\varphi_M(z) > 0$ leads to a wage rise for all routine workers; now consider a case $0 < \frac{d\ln\varphi_Y(z)}{dz} < \frac{d\ln\varphi_M(z)}{dz} = \frac{d\ln\varphi_L(z)}{dz} - \epsilon$, and an increase of $d\ln\varphi_M(z)$ by $\epsilon$ so that $\frac{d\ln\varphi_M(z)}{dz} = \frac{d\ln\varphi_L(z)}{dz}$. Given that $z_0$ would increase only when $dInc > 0$ from (5), it is easy to show that in the routine occupation there would always be some wage losers and winners according to their skill level.

RBTC.

### 3.3 RBTC vs. SBTC

It has become evident from the literature about job polarization that the most important difference between RBTC and the skill-biased technical change (SBTC) hypothesis 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:

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

with income definition (18) modified accordingly. Assume $d\kappa_Y > d\kappa_M > 0$;[29] 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 will find it attractive to move to $X$ firms where they task-upgrade and earn better wages: $z_0$ shifts left, as well as $z_1$ (the latter in order to restore the balance between 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. Clearly, these predictions contradict the stylized facts.

[29] Alternatively, we could assume that $d\ln\varphi_Y(z) > d\ln\varphi_M(z) > 0$; conclusions would be unaffected, as we illustrate in the numerical exploration reported in the Appendix.

### 3.4 RBTC vs. the demand-composition shift hypothesis

Some authors have suggested that labor market polarization could be driven by changes in preferences rather than by 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 health assistance, that is for 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 is this likely to impact on the labor market? The answer is provided in the following Figure 4, where it is shown that neither job nor wage polarization can result from such a change.

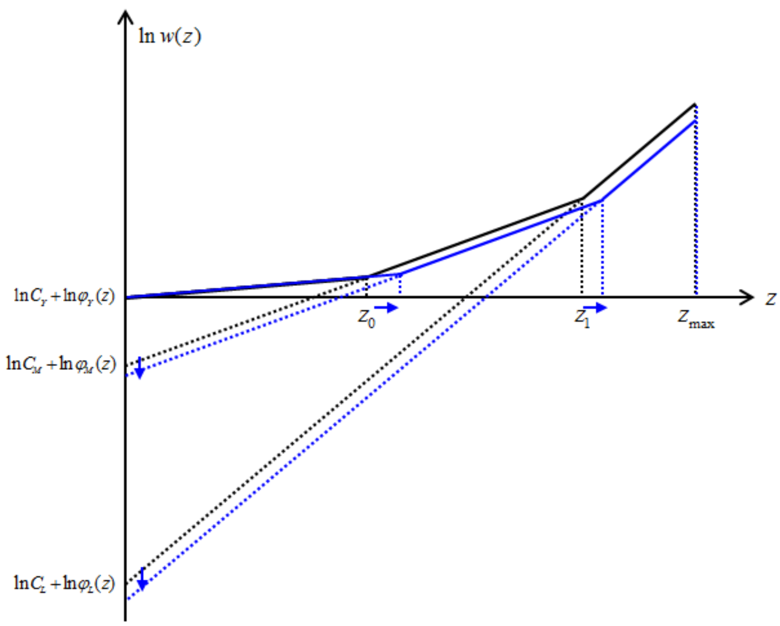


Figure 4: The effect of a preference shift in favor of service occupations.

To understand why, consider the effects of an exogenous reduction of $\beta$ in (1). The direct effect is to increase the relative price of service occupations, as well as the relative wage of workers performing those tasks (because $C_Y$ is the numeraire price, this reduces $C_M$ and $C_L$ in equal proportions), making it attractive for lower-skilled repetitive-task workers to task-downgrade and move into $Y$ jobs: $z_0$ shifts to the right. $X$ firms are then forced into restructuring, reducing wages in oversized headquarter-type activities (the fall of $C_L$ will therefore exceed that of $C_M$); the least talented among the workers engaged in such activities now find it profitable to task-downgrade into more repetitive job-types: $dz_1 > 0$. 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.

# 4 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 will have identical effects on the labor market in the North. We shall argue that, though this intuition is likely to be correct, it tends to be oversimplifying.

## 4.1 Opening the economy: offshore outsourcing repetitive tasks

We now assume that the two complementary intermediate inputs necessary to produce varieties of the final good $X$ are geographically separable: though non-routine cognitive tasks can only be produced domestically, in contrast, repetitive tasks can now either be performed locally, or in the South where marginal production (including transportation) costs $C_M^*$ are lower: $C_M^* = \theta C_M$, $\theta < 1$.[30] Offshore outsourcing however involves specific fixed costs $F_I$ . There is ample empirical evidence (a) that, everything else equal,

[30] One could of course argue that foreign labor costs will respond positively to the development of multinational activities. Clearly, the fact that offshore outsourcing has emerged as a major political issue for more than two decades suggests that $\theta$ is quite inelastic. Making $\theta$ endogenous would therefore only mitigate the conclusions at the cost of considerable complications.

multinationals (MNEs) are systematically more efficient than non-MNEs,[31] and (b) that when firms switch from national to multinational, they experience significant technological upgrading.[32] This clearly suggests that different technologies, some more efficient than others, are available, and that only a subset of firms, mostly multinationals, are able to take advantage of the best technologies, presumably because of the higher fixed costs involved. We capture this by introducing two different technologies for producing non-routine cognitive tasks, a high ($H$) and a low ($L$) technology. Technology $H$ is cheaper to operate but more expensive to set-up than tech $L$ so that $F_L < F_H$ and $C_L > C_H$, where $F_j$ and $C_j$ ($j = L, H$) denote respectively fixed and marginal production costs, and the subscript refers to technology types. We assume that $F_I$ and $\theta$ are such that, in equilibrium, only firms using the high technology are profitable enough to face the set-up cost of offshoring and therefore to take advantage of lower variable costs of producing repetitive intermediate inputs abroad. Hence, all high-tech firms are multinationals, and all low-tech firms are domestic-only firms. The latter firms are therefore identical to the firms of our closed economy, so that we can add a subscript $L$ to our previous notations to identify these firms.

We naturally assume that the best workers have a comparative advantage on the high technology, and complement condition (7) by imposing that:

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

with $\varphi_H(z_{\min}) = 1$. These assumptions ensure that in equilibrium, with competitive labor markets, among those workers performing non-routine cognitive tasks, the best will endogenously allocate themselves to MNEs. Let $z_2 \in (z_1, z_{\max})$ be the equilibrium skill-threshold separating those non-routine cognitive workers that are employed in domestic-only firms (those with $z \in (z_1, z_2)$) from those employed by MNEs (those with $z \in [z_2, z_{\max}]$). The former will earn wages $w(z) = C_L \varphi_L(z)$, and the latter will earn $w(z) = C_H \varphi_H(z)$, with the measured-in-efficiency-units wages $C_L$ and $C_H$ tied together

[31] See e.g., Doms and Jensen (1998), Conyon, Girma, Thompson 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 Wagner (2011) and Schwörer (2013).

[32] See e.g., Navaretti, Castellani and Disdier (2006) for a discussion, and some empirical evidence, on technological upgrading related to firms switching from national to multinational.

by an indifference condition:

$$C_L \varphi_L(z_2) = C_H \varphi_H(z_2). \tag{21}$$

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

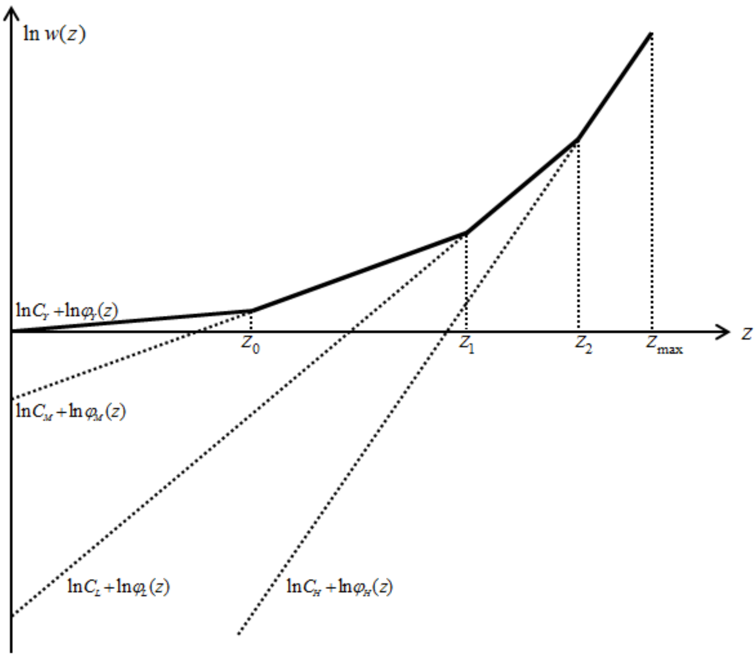


Figure 5: The open economy equilibrium wage distribution.

MNEs compete with domestic-only firms on monopolistically competitive product markets. We know from (12) that the $N_L$ domestic-only firms will charge prices $p_L$:

$$p_L = p_L(i) = \frac{\sigma}{\sigma - 1}\left(C_L + C_M\right) \qquad i \in N_L \ ; \tag{22}$$

with household preferences unchanged, and symmetry imposed within the high-tech subgroup, MNEs will all charge the same price, with constant optimal mark-up rate:

$$p_H = p_H(i) = \frac{\sigma}{\sigma - 1}\left(C_H + \theta C_M\right) \qquad i \in N_H \tag{23}$$

where $N_H$ is the number of existing MNEs. Observe that multinationals will charge lower prices than their national-only competitors, as realism suggests.

Equilibrium condition (13) for good $Y$ is unchanged, and (15), (16) and (17) still hold for domestic-only firms after substitution of $z_2$ for $z_{\max}$ in the integral signs (and after obvious adjustments in notation: $N, x, F$ becoming $N_L, x_L, F_L$). Multinationals produce $x_H = x(i)$, $i \in N_H$; making use of the Leontief technology (6), the total amount of domestic labor employed by MNEs can be written as:

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

which is equal to the total amount of labor employed abroad. Here again, for convenience, we have expressed real fixed costs in terms of foregone output volumes.

Free entry ensures no extra-normal profits in equilibrium, so that (17) holds for domestic-only firms (after adjusting notations), and the condition

$$\frac{1}{\sigma} p_H x_H = (C_H + \theta C_M) \cdot (F_H + F_I) \qquad i \in N_H \tag{25}$$

fixes the number of MNEs in equilibrium.

Domestic income follows from full employment of domestic production factors,

$$Inc = C_Y \int_{z_{\min}}^{z_0} \varphi_Y(z) dG(z) + \kappa_M C_M \int_{z_0}^{z_1} \varphi_M(z) dG(z) + C_L \int_{z_1}^{z_2} \varphi_L(z) dG(z) + C_H \int_{z_2}^{z_{\max}} \varphi_H(z) dG(z) \tag{26}$$

and wages paid to foreign workers by multinationals equal the (variable) cost of producing repetitive input tasks abroad:

$$Inc^* = \theta C_M \int_{z_2}^{z_{\max}} \varphi_H(z) dG(z). \tag{27}$$

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

$$x^{d*}(i) = \left(\frac{P_X}{p(i)}\right)^{\sigma} \frac{Inc^*}{P_X} \qquad i \in N = N_L \cup N_H \tag{28}$$

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

$$x(i) = x^d(i) + x^{d*}(i) \qquad i \in N = N_L \cup N_H \tag{29}$$

which completes the open economy version of our model.

## 4.2 RBTC in the open economy

Before addressing the issue of rising globalization, we discuss how our previous assessment of the RBTC hypothesis could possibly be affected by the presence of MNEs. For this, we can replicate the reasoning of Section 3.2: clearly, with $z_2$ temporarily kept fixed, nothing will be different. It is immediate to check that with $z_2$ unchanged, though the cost ratio $C_L/C_H$ remains unchanged (in addition to $C_M/C_M^*$ that is fixed by assumption), the output price ratio $p_L/p_H$ does not necessarily remain constant, as that will depend on the initial marginal input-cost shares. Changes in $p_L/p_H$ will be $\gtreqless 0$ $iff$ $C_H \lesseqgtr \theta C_L$, that is, $iff$ $\varphi_L(z_2) \lesseqgtr \theta\varphi_H(z_2)$.[33] Thus, at given $z_2$, if the technology gap $\varphi_H(z_2) - \varphi_L(z_2)$ is large enough, $X$ varieties from multinational 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 will have to be pulled out of the national-only competitors. Multinationals achieve this by offering better wages: $z_2$ shifts leftward as $C_H$ is increased, pushing $z_1$ further to the left hence amplifying the ongoing labor market polarization.[34] 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

[33] Totally differentiating from (12) and (23), we get: $d(\frac{p_L}{p_H}) = d(\frac{C_L+C_M}{C_H+\theta C_M}) = (\frac{C_L}{C_H+\theta C_M})^2 \left[\left(\frac{C_H}{C_L} - \theta\right) d(\frac{C_M}{C_L}) - (1 + \frac{C_M}{C_L}) d(\frac{C_H}{C_L})\right]$, where $d(\frac{C_M}{C_L}) < 0$ (see Footnote 26) and $d(\frac{C_H}{C_L}) = 0$ at a given $z_2$. Therefore, $d(\frac{p_L}{p_H}) \gtreqless 0$ $iff$ $C_H \lesseqgtr \theta C_L$; i.e. $iff$ $\varphi_L(z_2) \lesseqgtr \theta\varphi_H(z_2)$ from (10), (11) and (21).

[34] 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.

initial equilibrium value.[35] In this case, therefore, the conclusions from the closed economy analysis extend to the open economy: the presence of multinational firms tends to amplify the labor market transformations induced by RBTC. This case is displayed in Figure 6.

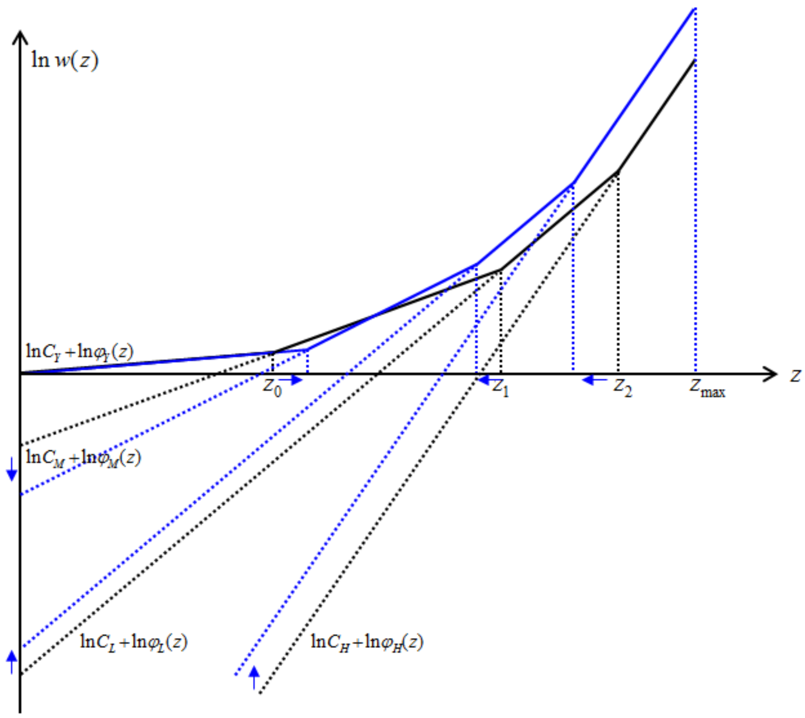


Figure 6: The effects of RBTC on the equilibrium wage distribution when the tech-gap between MNEs and non-MNEs is large enough.

But 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

[35] Indeed, making use of (17) and (25), after substituting out prices and output (from (12), (23), (3), (28) and (29)), it is easy to show from the ratio $\frac{p_L x_L}{p_H x_H}$ that, in equilibrium, $\frac{C_L+C_M}{C_H+\theta C_M} = \left[\frac{F_H+F_I}{F_L}\right]^{1/\sigma}$, a constant.

$\sigma$: the more $X$ varieties are differentiated ($\sigma$ low), the more likely it is that RBTC will be consistent with the stylized facts.[36]

Summing-up, we have shown in this section that, in an open economy, the presence of MNEs will amplify, mitigate or could even possibly counter, the direct effect of RBTC on the job and wage distributions. Observe that this result does not depend on which of the two alternative definitions of RBTC is adopted (that is, with or without a change of slope of the skill-productivity schedule in repetitive occupations). It is the efficiency gap between MNEs and non-MNEs that plays here the crucial role: the lower this gap, the less likely it is that RBTC will cause labor market polarization consistent with the data (Footnote 33). Though empirical investigations clearly indicate that RBTC has indeed contributed to this polarization, our results suggest that it might not always be the case in the future.

### 4.3 Rising globalization

Increased globalization can take two non-exclusive forms in this model: a lower fixed cost of engaging in offshore outsourcing activities ($dF_I < 0$), and a lower marginal cost of producing repetitive tasks abroad ($d\theta < 0$), the latter interpreted to include transportation costs.[37] Lower fixed costs $F_I$ directly induce technology upgrading by firms in the $X$ industry: an increasing number of low-tech producers find it profitable to turn multinational and switch to high-tech.[38] 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:[39] 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[40]. This simultaneous

[36] 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 so that the equilibrium skill threshold $z_2$ remains unchanged.

[37] Explicitly introducing ice-berg transportation costs is straightforward but only complicates without adding insight.

[38] 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 $z_0$.

[39] 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 $z_0$ .

[40] 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

technology upgrading by firms and task upgrading by workers induced by globalization unambiguously increase real domestic income,[41] and consequently the demand for the competitive good, requiring more labor in that sector: $dz_0 > 0$ as relative wages rise in low-skill non-repetitive non-cognitive tasks and labor pours out of the intermediate repetitive 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.[42] The new equilibrium wage distribution is shown in Figure 7, and clearly displays job and wage polarization.[43]

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.

[41] See Jung and Mercenier (2008) for a formal demonstration.

[42] The magnitude of the thresholds' changes will of course depend, among other things, on task switching costs of workers, costs which we assume implicitly included in the firms' fixed costs. See Artuç and McLaren (2012) for a recent investigation of the role of occupational mobility on trade induced effects on wage inequality.

[43] Though offshore outsourcing of intermediate inputs still explains the bulk of North-South trade, recent spectacular economic growth of some developing countries (such as China) increasingly draws attention to North-South trade in final goods too: see e.g., Autor, Dorn and Hanson (2012). Our framework can also be easily adapted for that. Now, interpreting $H$ firms as exporters – producing $m$ also domestically –, we have $\kappa_M \int_{z_0}^{z_1} \varphi_M(z)dG(z) = \int_{z_1}^{z_2} \varphi_L(z)dG(z) + \int_{z_2}^{z_{\max}} \varphi_H(z)dG(z)$ and $\frac{p_L}{p_H} = \frac{C_L+C_M}{C_H+C_M} = \left[\frac{F_H+F_I}{F_L}\right]^{1/\sigma}$, with $F_I$ now interpreted as an exporting-specific set-up cost. Totally differentiating the former at a given $z_0$, we get: $\frac{dz_1}{dz_2} = \frac{\varphi_L(z_2)dG(z_2)-\varphi_H(z_2)dG(z_2)}{\kappa_M \varphi_M(z_1)dG(z_1)+\varphi_L(z_1)dG(z_1)} < 0$. Then, from (10), (11) and (21), it is easy to show that trade liberalization ($dF_I < 0$) leads to a fall in $z_2$ and a rise in $z_1$, with $d(\frac{C_H}{C_L}) > 0$. The second order income effect on $z_0$ would only mitigate such adjustments without affecting them qualitatively.

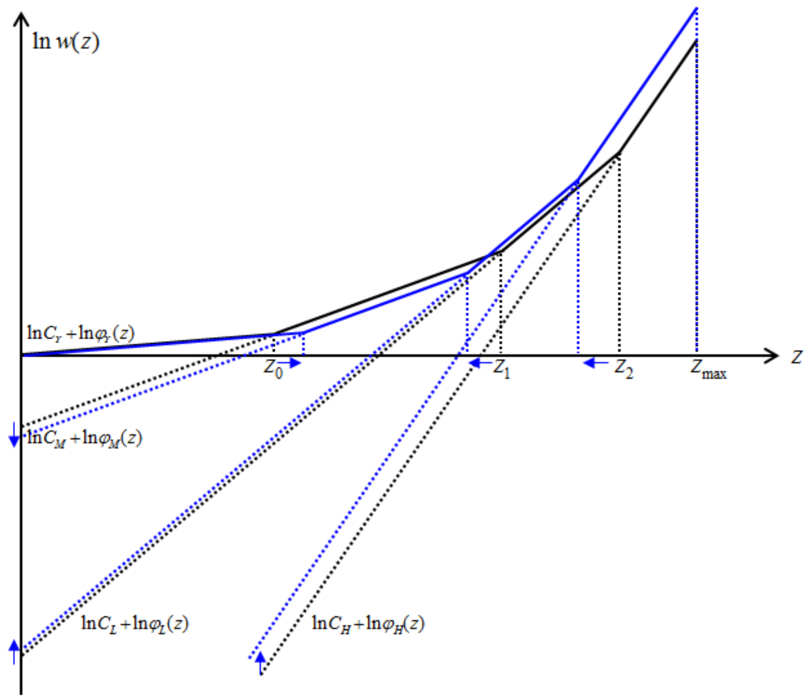


Figure 7: The effect of rising globalization on the equilibrium wage distribution.

RBTC and rising globalization can therefore have very similar effects. 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 the evidence we have today seems to militate against such a possibility (see for instance Goos and Manning, 2007) it is possible that in the future, as the relative intensity of these two forces change, empirical results will uncover such opposing effects. We conclude that the two shocks are likely to jointly cause current labor market polarization.

A second important difference is that, with rising globalization, all workers that remain allocated to performing repetitive tasks suffer a same proportional wage loss, independently of their skill level. The reason is that globalization acts as a demand shock on these repetitive tasks, inducing demand substitution in favor of foreign suppliers. 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. Secondly, a contraction of the 50-10 log-wage differential appears to be a robust consequence of the globalization shock[44] though it is only one among other possible outcomes of RBTC. In contrast, only RBTC induces wage inequalities to rise within the same repetitive occupations (when controlling for composition effects). 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 (a stylized fact). 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).[45]

Using a parameterized version of the model, we supplement this theoretical discussion by a numerical exploration in an appendix. There, we report results for the four explanations that have been suggested in the literature to explain recent labor market transformations, and that we have investigated in the paper, namely RBTC, SBTC, demand-composition shift due i.a. to population ageing, and finally globalization. The numerical exploration confirms the conclusions from our theoretical discussion.

# 5 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

[44] 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.

[45] Empirical evidence of the impact of trade on wage inequality has been mixed. Responsible for this is presumably an endogeneity problem: trade with less developed countries itself could spur technical change. Recent work by Bloom, Draca and Reenen (2011) suggests that about 15% of European technology upgrading over the period 2000-2007 could be due to Chinese import competition, of which about half due to *within-firm* technical upgrading, and half due to *between-firm* reallocation. This indicates that offshoring might have contributed to RBTC within firms (increase of the slope of $\ln \varphi_M(z)$). Our stylized model does not account for this offshoring-induced RBTC.

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. In this simplified set-up, 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 have shown 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 task up-grade or down-grade endogenously because of changing comparative advantages.

The analysis has then been generalized to the open economy within a globalized world. To the endogenous task up-grading or down-grading of workers, globalization adds the possibility for firms to endogenously choose the geographic location –locally or offshore– of part of their production and, doing so, to up-grade or down-grade their production technology. 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 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 have been offered. 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.[46]

[46] For a very different stand on this, see a recent paper by Harrigan and Reshef (2011). It is however

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 equipment will boost the productivity of workers performing routine tasks can hardly be perceived as unlikely.

unclear how their framework could explain the recently observed polarization of the labor market.

# Appendix : A numerical illustration

## A.1 The initial equilibrium

In this Appendix, 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. We set $\beta = 0.90$ for household preferences. We follow Krugman (1991) and choose $\sigma = 4$ for the differentiation elasticity.[47] We assume a uniform density distribution $g(z)$ for skills. Consistently with our graphical representation in Figure 1, technologies are assumed log-linear. We set: $\ln \varphi_Y(z) \approx 0.930 * z$; $\ln \varphi_M(z) = 1.10 * \ln \varphi_Y(z)$; $\ln \varphi_L(z) \approx 1.435 * z$; $\ln \varphi_H(z) = 1.10 * \ln \varphi_L(z)$.

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 (Markusen, 2002). We choose the following relative fixed costs: $F_L = 1.00$; $F_H + F_I = 1.62$.

The previous assumptions on the technologies imply a calibrated value of $\theta \approx 0.90$. The equilibrium skill thresholds are then chosen as: $z_{\min} = 0.00$; $z_0 \approx 0.18$; $z_1 \approx 0.74$; $z_2 \approx 1.00$; $z_{\max} \approx 1.06$.

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:

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

These shares are quite reasonable, and suggest that the values chosen for the parameters bear some realism.[48]

[47] See Broda and Weinstein (2006) for a recent estimate in more disaggregate product categories.

[48] The values of the parameters characterizing the different technologies were actually calibrated to reproduce approximately U.S. employment and GDP shares: see Autor and Dorn (2009).

## A.2 Comparing results from competing assumptions

Table A1 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 A1, A2 and A3, 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%;[49] 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; also, within task-type 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.

[49] As we know –and indeed have checked– reducing $\theta$ has the same qualitative effects.

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

Table A1: Computed effects of alternative shocks (% changes).

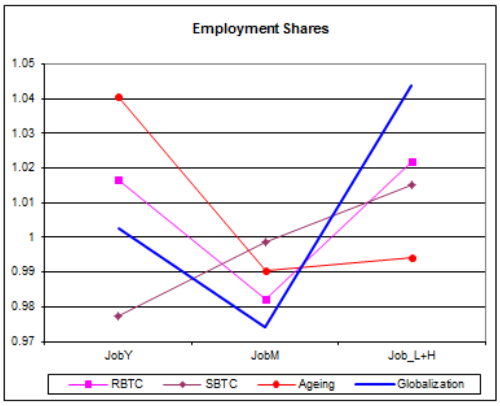


Figure A1: Effects of competing shocks on employment shares.

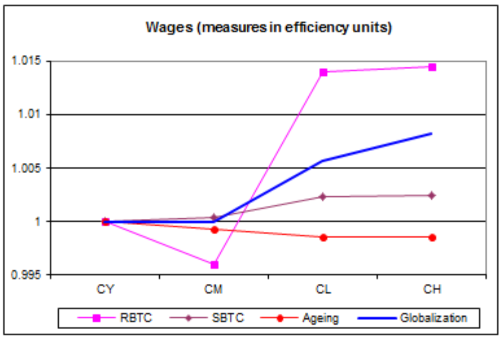


Figure A2: Effects of competing shocks on wages (measured in efficiency units).

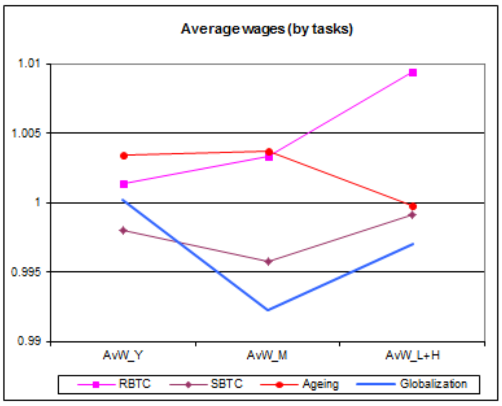


Figure A3: Effects of competing shocks on task-type average wages.

# References

[1] Abraham, F., J. Konings, and S. Vanormelingen. "The Effects of Globalization on Union Bargaining and Price-cost Margins of Firms." *Review of World Economics*, 145(1), 2009, 13–36.

[2] Acemoglu, D., and D. H. Autor. "Skills, Tasks, and Technologies: Implications for Employment and Earnings," in *Handbook of Labor Economics Vol. 4B*, edited by O. Ashenfelter, and D. Card. Amsterdam: North-Holland, 2011, 1043–171.

[3] Artuç, E., and J. McLaren. "Trade Policy and Wage Inequality: A Structural Analysis with Occupational and Sectoral Mobility." NBER Working Paper 18503, National Bureau of Economic Research, 2012.

[4] Autor, D. H., F. Levy, and R. J. Murnane. "The Skill Content of Recent Technological Change: An Empirical Exploration." *Quarterly Journal of Economics,* 118(4), 2003, 1279–333.

[5] Autor, D. H., L. F. Katz, and M. S. Kearney. "The Polarization of the U.S. Labor Market." *American Economic Review,* 96(2), 2006, 189–94.

[6] Autor, D. H., and D. Dorn. "Inequality and Specialization: The Growth of Low-Skill Service Jobs in the United States." IZA Discussion Paper 4290, Institute for the Study of Labor (IZA), 2009.

[7] Autor, D. H., D. Dorn, and G. H. Hanson. "The China Syndrome: Local Labor Market Effects of Import Competition in the United States." *American Economic Review,* 103(6), 2013, 2121–68.

[8] Bartel, A., C. Ichniowski, and K. Shaw. "How Does Information Technology Affect Productivity? Plant-Level Comparisons of Product Innovation, Process Improvement, and Worker Skills." *Quarterly Journal of Economics,* 122(4), 2007, 1721–58.

[9] Blanchard, E., and G. Willmann. "Trade, Education, and the Shrinking Middle Class." Working Paper, Universität Bielefeld, 2013.

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

[11] Bloom, N., M. Draca, and J. V. Reenen. "Trade Induced Technical Change? The Impact of Chinese Imports on Innovation, IT and Productivity." NBER Working Paper 16717, National Bureau of Economic Research, 2011.

[12] Broda, C., and D. E. Weinstein. "Globalization and the Gains from Variety." *Quarterly Journal of Economics,* 121(2), 2006, 541–85.

[13] Conyon, M. J., S. Girma, S. Thompson, and P. W. Wright. "The Productivity and Wage Effects of Foreign Acquisition in the United Kingdom." *Journal of Industrial Economics*, 50(1), 2002, 85–102.

[14] Cortes, G. M. "Where Have the Routine Workers Gone? A Study of Polarization Using Panel Data." Working Paper, University of Manchester, 2012.

[15] Costinot, A., and J. Vogel. "Matching and Inequality in the World Economy." *Journal of Political Economy*, 118(4), 2010, 747–86.

[16] Doms, M. E., and J. B. Jensen. "Comparing Wages, Skills, and Productivity between Domestically and Foreign-Owned Manufacturing Establishments in the United Sates," in *Geography and Ownership as Bases for Economic Accounting*, edited by R. E. Baldwin, R. E. Lipsey, and J. D. Richardson. Chicago: University of Chicago Press, 1998, 235–58.

[17] Dustmann, C., J. Ludsteck, and U. Schönberg. "Revising the German Wage Structure." *Quarterly Journal of Economics,* 124(2), 2009, 843–81.

[18] Ebenstein, A., A. Harrison, M. McMillan, and S. Phillips. "Why Are American Workers Getting Poorer? Estimating the Impact of Trade and Offshoring Using the CPS." NBER Working Paper 15107, National Bureau of Economic Research, 2009.

[19] Feenstra, R. C., and G. H. Hanson. "The Impact of Outsourcing and High-Technology Capital on Wages: Estimates for the United States, 1979–1990." *Quarterly Journal of Economics*, 114(3), 1999, 907–40.

[20] Firpo, S., N. Fortin, and T. Lemieux. "Occupational Tasks and Changes in the Wage Structure." IZA Discussion Paper 5542, Institute for the Study of Labor (IZA), 2011.

[21] Gathmann, C., and U. Schönberg. "How General is Human Capital? A Task-Based Approach." *Journal of Labor Economics,* 28(1), 2010, 1–49.

[22] Gibbons, R., L. Katz, T. Lemieux, and D. Parent. "Comparative Advantage, Learning, and Sectoral Wage Determination." *Journal of Labor Economics,* 23(4), 2005, 681–724.

[23] Goos, M., and A. Manning. "Lousy and Lovely Jobs: the Rising Polarization of Work in Britain." *Review of Economics and Statistics,* 89(1), 2007, 118–33.

[24] Goos, M., A. Manning, and A. Salomons. "Job Polarization in Europe." *American Economic Review,* 99(2), 2009, 58–63.

[25] Groes, F., P. Kircher, and I. Manovskii. "The U-Shapes of Occupational Mobility." Working Paper, University of Pennsylvania, 2010.

[26] Grossman, G. M., and E. Rossi-Hansberg. "Trading Tasks: A Simple Theory of Offshoring." *American Economic Review,* 98(5), 2008, 1978–97.

[27] Hansson, P. "Skill Upgrading and Production Transfer within Swedish Multinationals in the 1990s." *Scandinavian Journal of Economics,* 107(4), 2005, 673–92.

[28] Harrigan, J., and A. Reshef. "Skill Biased Heterogeneous Firms, Trade Liberalization, and the Skill Premium." NBER Working Paper 17604, National Bureau of Economic Research, 2011.

[29] Head, K., and J. Ries. "Offshore Production and Skill Upgrading by Japanese Manufacturing Firms." *Journal of International Economics,* 58(1), 2002, 81–105.

[30] Heckman, J. J., and J. Scheinkman. "The Importance of Bundling in a Gorman-Lancaster Model of Earnings." *Review of Economic Studies,* 54(2), 1987, 243–55.

[31] Helpman, E., M. J. Melitz, and S. R. Yeaple. "Export versus FDI with Heterogeneous Firms." *American Economic Review,* 94(1), 2004, 300–16.

[32] Helpman, E., O. Itskhoki, M.-A. Muendler, and S. Redding. "Trade and Inequality: From Theory to Estimation." NBER Working Paper 17991, National Bureau of Economic Research, 2012.

[33] Ikenaga, T., and R. Kambayashi. "Long-term Trends in the Polarization of the Japanese Labor Market: The Increase of Non-routine Task Input and Its Valuation in the Labor Market." Working Paper, Hitotsubashi University, 2010.

[34] Jung, J., and J. Mercenier. "A Simple Model of Offshore Outsourcing, Technology Upgrading and Welfare." THEMA Working Paper 2008-21, Université de Cergy-Pontoise, 2008.

[35] Kambourov, G., and I. Manovskii. “Rising Occupational and Industry Mobility in the United States: 1968–97.” *International Economic Review,* 49(1), 2008, 41–79.

[36] Kambourov, G., and I. Manovskii. “Occupational Specificity of Human Capital.” *International Economic Review,* 50(1), 2009, 63–115.

[37] Katz, L. F., and D. H. Autor. “Changes in the Wage Structure and Earnings Inequality,” in *Handbook of Labor Economics Vol. 3A*, edited by O. Ashenfelter, and D. Card. Amsterdam: North-Holland, 1999, 1463–555.

[38] Krugman, P. R. “Is Bilateralism Bad?,” in *International Trade and Trade Policy*, edited by E. Helpman, and A. Razin. Cambridge: MIT Press, 1999.

[39] Manning, A. “We Can Work It Out: The Impact of Technological Change on the Demand for Low-Skill Workers.” *Scottish Journal of Political Economy,* 51(5), 2004, 581–608.

[40] Markusen, J. *Multinational Firms and the Theory of International Trade.* Cambridge: MIT Press, 2002.

[41] Mendelson, H. “Organizational Architecture and Success in the Information Technology Industry.” *Management Science,* 46(4), 2000, 513–29.

[42] Moscarini, G., and K. Thomsson. “Occupational and Job Mobility in the US.” *Scandinavian Journal of Economics,* 109(4), 2007, 807–36.

[43] Navaretti, G. B., D. Castellani, and A.-C. Disdier. “How Does Investing in Cheap Labour Countries Affect Performance at Home? France and Italy.” CEPR Discussion Paper 5765, Center for Economic Policy Research, 2006.

[44] Poletaev, M., and C. Robinson. “Human Capital Specificity: Evidence from the Dictionary of Occupational Titles and Displaced Worker Surveys, 1984–2000.” *Journal of Labor Economics,* 26(3), 2008, 387–420.

[45] Schwörer, T. “Offshoring, Domestic Outsourcing and Productivity: Evidence for a Number of European Countries.” *Review of World Economics*, 149(1), 2013, 131–49.

[46] Spitz-Oener, A. “Technical Change, Job Tasks, and Rising Educational Demands: Looking Outside the Wage Structure.” *Journal of Labor Economics,* 24(2), 2006, 235–70.

[47] Wagner, J. “Offshoring and Firm Performance: Self-selection, Effects on Performance, or Both?” *Review of World Economics*, 147(2), 2011, 217–47.

[48] Yeaple, S. R. "A Simple Model of Firm Heterogeneity, International Trade, and Wages." *Journal of International Economics,* 65(1), 2005, 1–20.