Online appendix for

"Heterogeneous Trade Costs and Wage Inequality"

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A Technology Adoption

Our baseline model emphasized the role of the IT revolution for the C-globalization, as argued by Blinder (2006). However, the C-globalization is also the result of adopting new technologies which replace middle and low-skill jobs (Autor et al., 2003). It is therefore natural to investigate the effect of different types of trade on the incentives of firms to adopt new technologies.

Consider an extension of our baseline model in which agents can freely choose between two technologies. There is an Old Technology which can only benefit from trade in L-globalization intermediates. There is a New Technology which uses more skill-intensive inputs (e.g., computerization) and benefits from C-globalization trade. This New Technology only uses tasks as inputs. More precisely,

$$\text{Old Technology}: \quad h^{\alpha}\left(\int_0^1 \ln I(z)dz\right)^{1-\alpha},$$
$$\text{New Technology}: \quad h^{\alpha}\left(\int_{\bar{z}}^1 \ln I(z)dz\right)^{1-\alpha}.$$

We assume that high-skill agents choose the production technology. Note that the optimal technology is the one that maximizes the bundle of inputs. These bundles in equilibrium are

$$B^{Old} = \int_0^{z_I} \ln(\tilde{p}^S(z))^{-1}dz + \int_{z_I}^1 \ln(\tilde{p}^N(z))^{-1}dz, \quad (1)$$
$$B^{New} = \int_{\bar{z}}^{z_{II}} \ln(\tilde{p}^S(z))^{-1}dz + \int_{z_{II}}^1 \ln(\tilde{p}^N(z))^{-1}dz, \quad (2)$$

where $\tilde{p}^i(z) = \frac{B}{(1-\alpha)Y}p^i(z)$ denotes a renormalized price in country i.

Proposition 1 *Let $\hat{z}_{II}(z_I)$ denote the threshold above which the New Technology starts to be adopted. The threshold $\hat{z}_{II}(z_I)$ is (weakly) increasing in z_I.*

Proof Define $\Delta B(z_I, z_{II}) \equiv B^{New} - B^{Old}$, the difference in profits between the two technologies,

$$\Delta B(z_I, z_{II}) = \int_{\bar{z}}^{z_{II}} \ln\left(\frac{\tilde{p}^S(z)}{\tilde{p}^N(z)}\right)^{-1} dz - \left(\int_0^{z_I} \ln(\tilde{p}^S(z))^{-1} dz + \int_{z_I}^{\bar{z}} \ln(\tilde{p}^N(z))^{-1} dz\right). \quad (3)$$

The first term in (3) summarizes the relative benefit of adopting the New Technology, whereas the second captures the additional benefit of using the Old Technology. The equation $\Delta B(z_I, z_{II}) = 0$ implicitly defines the threshold $\hat{z}_{II}(z_I)$ above which the New Technology starts to be adopted. The partial derivative of equation (3) with respect to z_{II} is positive, because $p^N(z) \geq p^S(z)$ in the trade region. The partial derivative of equation (3) with respect to z_I is negative. The first term decreases in z_I and the second term (in parenthesis) increases. The result for the first term comes directly from differentiation of prices. To obtain the sign of the second term, note that by Leibniz's rule, we have that the partial derivative is

$$\ln\left(\frac{\tilde{p}^N(z_I)}{\tilde{p}^S(z_I)}\right) + \int_0^{z_I} \frac{\partial}{\partial z_I} \ln(\tilde{p}^S(z))^{-1} dz + \int_{z_I}^{\bar{z}} \frac{\partial}{\partial z_I} \ln(\tilde{p}^N(z))^{-1} dz. \quad (4)$$

The first term in (4) is non-negative as long as $p^N/p^S \geq 1$ for traded goods, which is assumed to be true to derive the equilibrium. The second and third terms can be expressed as

$$\frac{(1 - \bar{z} + 2z_I)(1 - \bar{z})}{1 - z_I^2}, \quad (5)$$

which is positive. Therefore, using the implicit function theorem it follows that $\hat{z}_{II}(z_I)$ is increasing in z_I. ∎

There are two economic forces driving Proposition 1. First, the Old Technology benefits from the L-globalization by replacing northern intermediates by cheaper southern intermediates. Second, the prices of tasks increase with L-globalization. As a result, the relative profitability of the Old Technology increases with trade in the L-globalization.

This simple technology choice model suggests that the effect of trade on technology adoption depends on the "type of trade" and the "type of technology". The L-globalization complements Old Technology and the C-globalization complements New Technology. However, L-globalization delays the adoption of New Technology and thus can be seen as a substitute for adoption of New Technology. If we think of New Technology as computerization, along the lines of Autor et al. (2003), Proposition 1 can be interpreted as saying that there is no dichotomy between offshoring of services and computerization. The labor literature has proposed the computerization hypothesis to account for the differential loss of middle-skill jobs and wage polarization (Autor et al., 2003). In our model, computerization is needed to take advantage of the C-globalization. Therefore, computerization leads to offshoring and, conse-

quently, to the loss of middle-skill jobs and wage polarization in the North. This extension implies that trade in L-globalization delays computerization. This may be a rationale for why middling and wage polarization appear sooner in the relatively less open northern countries (e.g., the United States) than in relatively more open countries (e.g., the United Kingdom).

B Two extensions with final good production in the South

First, we present a direct extension of our baseline model in which we allow for final good production in the South. We show analytically that the results for the North continue to hold. Then, we show numerically that the results for the South hold, provided that there is enough trade during the L-liberalization (that is, if $0 < \underline{z} < z_I$).

Second, we present a simple modification of the model for which we can derive analytical solutions for *both* North and South. This model exhibits *exactly* the same qualitative behaviour that the first extension.

B.1 Baseline model with final good production in the North and South

We present a version of our baseline model with production in both North and South. Accordingly, there are three different skill levels in the North and the South. Assume that a fraction φ^i of middle-skill agents in country i obtains further education, becoming high-skill agents. Thus, country i is populated by a fraction $\varphi^i\theta^i$ of high-skill agents, $(1-\varphi^i)\theta^i$ of middle-skill agents, and $1-\theta^i$ of low-skill agents. We assume that $\varphi^N \geq \varphi^S$. That is, North is relatively abundant in high-skill agents.

The production technologies are the same as in the baseline model, with the only difference that now the South produces final good and, thus, demands inputs. The rest of the set-up of the model is as in section 3 of the paper.[1] The procedure for solving the equilibrium allocations

[1] We maintain Assumption 1, rewritten to account for the new relative supplies. That is, we assume that $z_{II} \leq z^*$, where z^* is implicitly defined by

$$\left(\frac{\theta^S(1-\varphi^S)}{1-\varphi^N}\frac{(1-z^{*2})\varphi^N}{z^{*2}\varphi^N\theta^N+\varphi^S\theta^S}\right)^{z^*}\left(\frac{1-\theta^S}{1-\theta^N}\frac{(1-z^*)^2\varphi^N\theta^N}{(1-(1-z^*)^2)\varphi^N\theta^N+\varphi^S\theta^S}\right)^{1-z^*}=1.$$

The difference with the expression in the main text is that now there is an extra term coming from the southern demand for inputs. This assumption requires that the relative supply of low-skill workers in the South is high compared to the northern relative supply of middle.

is the same as in the baseline model. Wages can be expressed as

$$w_h^N = \alpha \frac{Y^N}{\theta^N \varphi^N} \tag{6}$$

$$w_m^N = (1-\alpha) Y^N \frac{1 - z_I^2 - z_{II}^2 + \overline{z}^2}{2(1-\varphi^N)\theta^N}, \tag{7}$$

$$w_l^N = (1-\alpha) Y^N \frac{(1-z_I)^2 + (1-z_{II})^2 - (1-\overline{z})^2}{2(1-\theta^N)}, \tag{8}$$

$$w_h^S = \alpha \frac{Y^S}{\theta^S \varphi^S} \tag{9}$$

$$w_m^S = (1-\alpha) \frac{Y^S + Y^N (z_I^2 + z_{II}^2 - \overline{z}^2)}{2\theta^S (1-\varphi^S)}, \tag{10}$$

$$w_l^S = (1-\alpha) \frac{Y^S + Y^N \left[1 - (1-z_I)^2 - (1-z_{II})^2 + (1-\overline{z})^2\right]}{2(1-\theta^S)}. \tag{11}$$

Our first main result is that by allowing final good production in the south, all the results for the North are the same.

Proposition 2 *All the comparative static results for the North coincide with the baseline model. In particular, this implies that the complementarity results apply in this case too.*

Proof The relative wages are identical to the main text (because of the linearity of wages in Y^N). ∎

It is harder to derive analytical results for the evolution of relative wages in the South. This is because the effect of globalization on relative wages depends on the income levels in both countries, and this results in a non-linear set of equations to be solved. To see this, note that the final good production in country i can be written now as

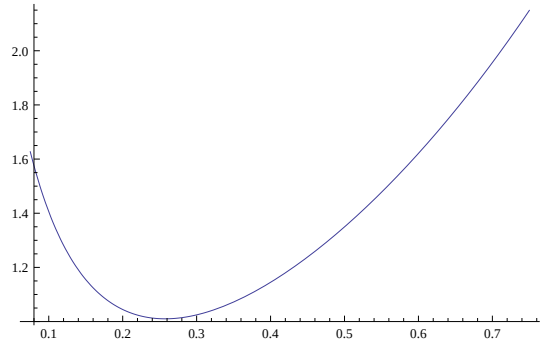
$$1 = \left(\frac{\alpha}{w_h^i}\right)^{\alpha} \left(\exp\left[\int_0^1 \ln\left(\frac{(1-\alpha)}{p^j(z)}\right) dz\right]\right)^{1-\alpha}, \tag{12}$$

where $p^j(z)$ is the cheapest price available for good z. Moreover, the prices of inputs can be expressed as

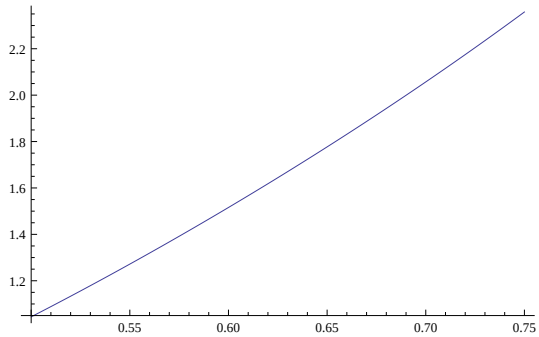
$$p^j(z) = w_m^{j^z} w_l^{j^{1-z}}, \qquad j = \{N, S\}. \tag{13}$$

Thus, we have an expression of output in terms of wages. Using equations (7) to (11) and (13) into (12) for $j = \{N, S\}$, we have a non-linear system of equations for $\{Y^N, Y^S\}$.

We solve for this problem numerically. We choose the parameters to be consistent with the Barro Lee data on education for 1990. In particular, we identify the high skill workers with the fraction of the population with some tertiary education, middle skill, with the percentage of the population with some secondary education and we attribute the rest to low skill. We



(a) Relative wage of middle- to low-skill workers in the L-globalization as a function of z_I.



(b) Relative wage of middle- to low-skill workers in the C-globalization as a function of z_{II}.

Figure 1: Relative wages in the South. See main text for a discussion of the choice of parameters.

select the North to match the US, which implies a supply of high skill of 43.1%, of middle skill of 47.2% and of low skill of 9.7%. For the South, we selected to match the average between India and Pakistan, which results in a supply of high skill of 3.2%, middle skill of 22.5% and of low skill of 74.3%. Figures 1a and 1b show the comparative statics of relative wage of middle to low skill in the South in the L- and C-globalizations, respectively.[2]

The qualitative result for the C-globalization is as in the baseline model. That is, the relative wage of middle- to low-skill decreases. The only difference is the presence of a U-shape pattern in the relative wage of middle to low-skill agents during the L-globalization. The reason is that now there is final good production and, therefore, demand for intermediates in the South. Two economic forces play a role. First, there is a direct demand effect, by which when demand of low skill tasks increases, the relative wage of low skill workers increases. Second, an increase in offshoring (i.e., an increase in z_I) translates into an increase in the relative demand of middle- to low-skill workers at the margin. The magnitude of this second effect depends crucially on the relative size of southern demand. If northern demand of intermediates is very large compared to southern demand, an increase in offshoring translates sooner into an increase in the relative wage because the demand for relatively more skill intensive intermediates increases faster. Note that in our baseline model there is no southern demand. Thus, only the second force is present. The assumption that we need (and we think it is reasonable) for the simple model presented in the text to caputre the same economic phenomena that this richer model is that the L-Globalization is "deep enough", in the sense that $z_I \geq \underline{z}$, where $\underline{z}$ denotes the point in which the relative southern wage starts to increase. This assumption guarantees that the relative wage of middle- to low-skill workers in the South is in an increasing region throught the L-Globalization.

Even though we do not provide a theorem stating that the qualitative results we find always

[2]The rest of the parameters shown in the simulations are $\bar{z} = .5$ and $\alpha = .8$. Results are robust to changing these two parameters.

hold, we have not found any parameter configuration in which the qualitative behavior of the southern relative wage is different. Moreover, in the simple variation of the model that we present in the next subsection, we can show *analytically* that the same qualitative behavior *always* happens, which strengthens our confidence on the results that we obtain from the simulations of this model because the economic forces at play are the same.[3]

B.2 Alternative Model with Decreasing Returns in Production

As in the previous subsection, we have three different skill levels in the North and the South. Country i is populated by a fraction $\varphi^i\theta^i$ of high-skill agents, $(1-\varphi^i)\theta^i$ of middle-skill agents, and $1-\theta^i$ of low-skill agents. We assume that $\varphi^N \geq \varphi^S$. That is, North is relatively abundant in high-skill agents.

To have analytically tractable results, we simplify the final good production technology. We assume that $y = B = \int_0^1 \ln I(z)dz$ and that *only* high skill agents have access to the final good production technology. Note that the intermediates are bundled in the same way as in the baseline model. However, there is no specific input of high-skill agents in the final good production (other than being able to operate the bundling technology). Thus, instead of having high-skill agents being paid their marginal product in a constant return to scale technology, we

[3]Note that in this model we can study the evolution of the relative wage of high-skill workers in the South. The relative wage of high- to middle-skill workers is decreasing for the most simulations (in some it can have an inverse U-shape, with the max located at low values of z). The reason is simple, as globalization progresses, the relative demand for middle- and low-skill workers increases, while relative demand for high-skill decreases.

A potential extension of this framework would be to incorporate the idea put forth in Matsuyama (2007), who assumes that international trade inherently requires more intensive use of skilled labor. This would generate an additional source of demand for southern high-skill workers as globalization progresses. In this case, the relative wage of southern high-skill workers could increase throughout the globalization process.

More specifically, one can proceed as follows. Assume that the production function of inputs to be exported, which we denote by I^X, differs from the domestic, I^H. This captures the idea that translation expertise, knowledge of international law, compliance with international standards, etc., which we label as exporting knowledge, are needed to export. Along the lines of Matsuyama (2007), assume that exporting knowledge is provided by high-skill agents. To capture this notion we consider the following production functions

$$I^H(z) = A\left(\frac{m^H(z)}{z}\right)^z\left(\frac{l^H(z)}{1-z}\right)^{1-z}, \tag{14}$$

$$I^X(z) = \frac{A}{\beta^\beta(1-\beta)^{1-\beta}}\left[\left(\frac{m^X(z)}{z}\right)^z\left(\frac{l^X(z)}{1-z}\right)^{1-z}\right]^\beta h(z)^{1-\beta}, \tag{15}$$

where $\beta \in (0,1)$, A is a Hicks-neutral productivity factor, $m^s(z)$ and $l^s(z)$ are middle and low skill agents working in sector $s \in \{H, X\}$, respectively, and $h(z)$ is exporting knowledge. High-skill agents need a fraction $1-\gamma$ of their labor endowment to run the final good technology. The reminder γ is devoted to supply exporting knowledge.

The return of exporting knowledge for southern high skill agents is $(z_I + z_{II} - \bar{z})(1-\beta)\frac{\varphi^N}{\gamma\varphi^S}\frac{\theta^N}{\theta^S}$. Proceeding as in the main text, one can compute the relative wages, adding the return to exporting knowledge for high-skill workers. It is clear that the comparative statics for the relative wages of high-skill workers will depend crucially on how much the demand for exporting knowledge increases with globalization, which is captured by the term γ. In particular, it can be shown that for $\gamma\varphi^S/\varphi^N$ smaller than a threshold, the relative wage of high- to middle- and high- to low-skill is increasing in z_{I} and z_{II}.

are assuming that they have access to a decreasing returns to scale production function and make profits out of operating it.

The rest of the set-up of the model is as in section 3 of the paper. The procedure for solving the equilibrium allocations is the same as in the baseline model.[4]

Proposition 3 *(L-Globalization) The equilibrium during the L-Globalization features the following properties:*

1. *North: The relative wages of middle- to low-skill workers and high- to middle-skill workers are increasing in z_I.*

2. *South: The relative wage of middle to low-skill agents decreases in z_I for $z_I < \tilde{z}_I$ and increases afterwards. The relative wage of high to middle and high to low-skill is decreasing in z_I.*

Proof Wages can be expressed as

$$w_m^N = \varphi^N \frac{1 - z_I^2 - z_{II}^2 + \overline{z}^2}{2(1-\varphi^N)}, \tag{16}$$

$$w_l^N = \varphi^N \theta^N \frac{(1-z_I)^2 + (1-z_{II})^2 - (1-\overline{z})^2}{2(1-\theta^N)}, \tag{17}$$

$$w_m^S = \frac{\varphi^S \theta^S + \varphi^N \theta^N (z_I^2 + z_{II}^2 - \overline{z}^2)}{2\theta^S(1-\varphi^S)}, \tag{18}$$

$$w_l^S = \frac{\varphi^S \theta^S + \varphi^N \theta^N \left[1 - (1-z_I)^2 - (1-z_{II})^2 + (1-\overline{z})^2\right]}{2(1-\theta^S)}. \tag{19}$$

Earnings of northern high skill agents are

$$w_h^N = \int_0^1 \ln I^N(z) dz - \int_0^1 p^N(z) I^N(z) dz. \tag{20}$$

Similarly, earning of southern high skill agents are

$$w_h^S = \int_0^1 \ln p^S(z)^{-1} dz - 1 = \ln A - \ln\left(w_m^S w_l^S\right)^{\frac{1}{2}} - 1$$

[4] Again, we keep the analogous version to Assumption 1. We assume that $z_{II} \leq z^*$, where z^* is implicitly defined by

$$\left(\frac{\theta^S(1-\varphi^S)}{1-\varphi^N} \frac{(1-z^{*2})\varphi^N}{z^{*2}\varphi^N\theta^N + \varphi^S\theta^S}\right)^{z^*} \left(\frac{1-\theta^S}{1-\theta^N} \frac{(1-z^*)^2\varphi^N\theta^N}{(1-(1-z^*)^2)\varphi^N\theta^N + \varphi^S\theta^S}\right)^{1-z^*} = 1.$$

The difference with the expression in the main text is that now there is an extra term coming from the southern demand for inputs. This assumption requires that the relative supply of low-skill workers in the South is high compared to the northern relative supply of middle.

For the comparative statics exercise, consider the North first. The partial derivatives of equations (16) and (17) with respect to z_I are negative. Thus, given that (20) is increasing in z_I, it follows that the relative wage of high- to middle-skill and middle- to low-skill workers are increasing in z_I. Note that by setting $z_{II} = \bar{z}$, the relative wage of middle- to low-skill workers is proportional to $\frac{1+z_I}{1-z_I}$, which is increasing in z_I.

For the South, the relative wage of middle to low-skill is

$$\frac{\varphi^S\theta^S + \varphi^N\theta^N z_I^2}{\varphi^S\theta^S + \varphi^N\theta^N\left[1-(1-z_I)^2\right]}\frac{1-\theta^S}{\theta^S(1-\varphi^S)}.$$

Define $\hat{\alpha} \equiv \frac{\varphi^S\theta^S}{\varphi^N\theta^N} \leq 1$. Taking the partial derivative of the relative wage of middle- to low-skill workers with respect to z_I shows that it is decreasing in z_I for $z_I < \tilde{z}_I(\hat{\alpha})$ and increasing afterwards, where $\tilde{z}_I(\hat{\alpha}) \equiv -\hat{\alpha} + \sqrt{\hat{\alpha}(1+\hat{\alpha})}$. Note that $\tilde{z}_I'(\hat{\alpha}) > 0$ and $\tilde{z}_I(0) = 0$. For the relative wage of high-skill to both low- and middle-skill, note that w_l^S and w_m^S are increasing in z_I, while w_h^S is decreasing. Therefore, the result follows. ∎

Thus, the qualitative behavior of relative wages is the *same* as in the previous subsection. With the only difference being that we can, in fact, provide analytical results for the North.

In what follows we assume that the C-Globalization starts with $z_I \geq \tilde{z}_I$. This implies that the relative wage of middle- to low-skill workers in the South is in a region increasing in L-Globalization trade.

Proposition 4 *(C-Globalization) The equilibrium during the C-Globalization features the following properties:*

1. *North: the relative wage of middle- to low-skill workers increases in z_I and in z_{II} for $z_{II} < \tilde{z}_{II}(z_I)$ and decreases afterwards. The relative wage of high- to middle-skill and high- to low-skill is increasing in z_{II} and decreases in z_I.*

2. *South: The relative wage of middle- to low-skill workers increases in z_{II} and z_I. The relative wage of high to middle- and high- to low-skill is decreasing in z_{II}.*[5]

Proof Consider the North first. The proof the relative wages of high to middle and high to low-skill being increasing in z_{II} follows from inspection of the wage equations and is analogous to proposition 3. Note that the relative wage of middle to low-skill workers is proportional to $\frac{1-z_I^2-z_{II}^2+\bar{z}^2}{(1-z_I)^2+(1-z_{II})^2-(1-\bar{z})^2}$. It can be shown that it is decreasing in z_{II} for $z_{II} < \tilde{z}_{II}(z_I) = 1 - z_I + \bar{z} - \sqrt{2(1-z_I)(\bar{z}-z_I)}$.

[5]The relative wage of the high-skill southern workers is decreasing in this model, as the relative demand for middle- and low-skill workers is increasing and hence, so is their price, reducing firms profits. As in the previous footnote, one could introduce exporting knowledge as an additional input for exporting à la Matsuyama, in which case one can revert this result (or obtain non-monotonic patterns).

Manipulation of the partial derivative of the relative wage of middle to low-skill workers with respect to z_{II} shows that it is is increasing in z_{II} and z_I if $z_I \geq \tilde{z}_I$. The remainder of the proof to derive the comparative statics of the relative wage for high skill agents is analogous to Proposition 3. w_l^S and w_m^S are increasing in z_{II}, while w_h^S is decreasing. Thus, the result follows. ∎

Proposition 5 *(Interdependence in the North) The threshold $\tilde{z}_{II}(z_I)$ below which the relative wage of middle skill workers in the North increases is increasing in z_I.*

Proof It follows from direct differentiation of $\tilde{z}_{II}(z_I)$.

Note that results in Propositions 3 , 4 and 5 are analogous to the baseline model. This implies that the results from the subsection "Two Souths and the Moving Band" also go through because the relative wages of middle- to low- skill workers in the South behave exactly the same as in the baseline model.

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