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International Trade and Human Capital Investment with Heterogeneous Firms and Workers: Modeling and Analysis

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Abstract: Though the importance of organizational behavior and human decision processes within firms for the firm performance has largely been recognized in the business and management literature, much less attention has been devoted to studying such implications in the international trade context. This paper develops a general-equilibrium trade model in which heterogeneous workers make an investment decision in acquiring advanced managerial skills and choose their optimal effort level based on their comparative advantage. In doing so, we show how globalization-induced human capital accumulation within firms leads to sustainable economic growth. We also show that workers' organizational belief and CEO's managerial vision may be an important element for the human capital formation within firms and for the performance of firms in a global economy.

Keywords: international trade; human capital investment; heterogeneous firms and workers; globalization; skill acquisition; labor productivity; organizational change; sustainable economic development and growth

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1. Introduction

Why some firms engage in international trade while the others focus only on the domestic market, and the impacts of trade liberalization (or more broadly, globalization) when firms differ, have long been some of the main concerns of trade economists. Addressing these issues, recent firm heterogeneity literature in international trade has discovered many systematic links between the characteristics of firms and their degree of internationalization. In particular, it is now widely documented that exporting firms are more productive than non-exporters and/or that more productive firms self-select into export markets (see, e.g., [1,2]).

Consequently, on the theoretical side such selection effects of trade have largely been modeled and examined by incorporating exogenously given firm-level productivity differences [3]. Another branch of modeling firm heterogeneity has been to assume exogenously given worker-level ability differences and consider firms' endogenous technological choice together with employment decisions (see, e.g., [4–6]). Some other papers model a continuum of tasks instead of a continuum of heterogeneous worker skills (see, e.g., [7,8]). All these approaches have also been generalized by assuming log-supermodularity between continuum of worker skills and continuum of tasks [9].

Though many important new insights have been gained at the aggregate level, all these approaches are, however, limited in studying intra-firm managerial mechanisms and the resulting strategic direction and performance of firms. It has been extensively discussed in the management literature that the human capital investment of workers within firms has a considerable influence for the overall performance of firms. For the human capital formation of firms, many researchers highlighted the importance of organizational behavior and human decision processes within firms. Additionally, the international entrepreneurship (IE) literature in international business and management has extensively studied the key role of entrepreneurial (and/or managerial) vision in the performance of international firms (see, e.g., [10–15]).

While the economic literature has largely neglected these issues, some exceptions are found. By formally modeling CEO's leadership style and/or vision, Rotemberg and Sloner [16,17] show that managerial preferences have an important effect on firm performance through encouraging incentives. Van den Steen [18,19] focuses on the sorting effect induced by managerial beliefs and shows that a firm attracts employees having similar beliefs to that of its manager and the shared beliefs have very pervasive performance effects for the firm. Additionally, some papers study how managerial characteristics can be determinants of firm boundaries [20] or investigate how competition fosters commitment of firms by interacting with leadership styles [21]. Though the important implications of organizational behavior and human capital investment on firm strategy and performance have been widely documented in the management literature during the last decades and some pioneering papers dealt with these implications in economics context, much less attention has been devoted to studying such implications in the international trade and/or globalization context.

In this paper, we make a first attempt in the literature (to our best knowledge) to bridge the gap. We develop a general-equilibrium trade model in which heterogeneous employees make an investment decision in acquiring advanced managerial skills and choose their optimal effort level based on their comparative advantage. Firms are free to enter the market and choose whether or not to enter the export market according to their status-quo technologies. The key element of the model is the interaction between workers' strategy-specific abilities and the strategy-specific technologies within firms. We consider two market strategies: localization vs. internationalization. Given the externalities between the workers' strategy-specific ability and the strategy-specific technologies used, as well as the existence of learning costs to obtain each strategy-specific managerial skill, workers endogenously sort into firms and tasks (production vs. management).

Given this setup, we investigate the impacts of globalization. We first investigate the effects of trade liberalization due to a fall in marginal trade cost. As will be shown later, trade liberalization increases the optimal effort level of exporting-firm managerial workers while decreases that of domestic-firm managerial workers; also, more production workers decide to invest in obtaining managerial skills and become managers in exporting firms. The expansion of high-tech exporting firms and the compression of low-tech domestic firms increase the overall productivity of the economy, and increase the aggregate welfare, which implies a sustainable economic development and growth. We also show that the effects of globalization-induced technological progress lead to very similar implications.

On the other hand, it is widely documented in the business and management literature that an individual worker follows a specific career path to be a specialist in a specific field. That is, being an international market specialist or being a national market specialist requires substantially different job training, and workers choose their career path based on their own beliefs and/or preferences (which can also be a part of individual's intrinsic ability). An individual worker's belief and goal setting then materialize as strategy-specific productivity. In this paper, we also consider such two-dimensional ability. This is one important departure from conventional models in international trade literature with heterogeneous workers and firms, where workers' ability has only been uni-dimensional so that more able (talented) workers sort automatically into exporting firms while less able (less talented) workers sort into national firms (see, e.g., [22–26]). Uni-dimensional ability frameworks inevitably lead to unrealistic results that all the workers in exporting firms are always paid higher wages than ones in national firms: there is one cutoff ability level and even the highest talented in national firms are paid less than the least talented in exporting firms. This is obviously very restrictive and simplistic assumption to study modern income inequality when looked at from the real business and management perspectives. Related to globalization and international entrepreneurship (IE) literature, a new type of highly international small and medium-sized enterprises (SMEs)—born global firms–have largely been emphasized in business academia. Though economic academia has been highlighting that on average exporting firms are larger and pay higher wages (see, e.g., [27–29] and references therein), born global firms have been regarded as very quickly emerging and influential since the 1980s in the real business world. See, e.g., Kuivalainen et al. [30] for a review of the literature on born global firms and the role of international entrepreneurial orientation.

Related to the literature of organizational behavior, we also extend the model by incorporating the externalities between workers' organizational belief and CEO's managerial vision, and study more explicitly the role of organizational behavior and human decision processes within firms in the firm performance. Since workers decide according to their own beliefs, workers with high beliefs on internationalization self-select to work as managers in exporting firms, while those with high beliefs on localization self-select to work as managers in domestic firms. The middling workers having relatively indifferent beliefs on both strategies self-select to work as production workers without making any investment to obtain managerial skills. Within firms, workers decide to invest and make efforts based on their own organizational belief, and workers having similar organization belief to the CEO's managerial vision have higher productivity due to the positive externality. In this case, globalization increases the most the productivity and income of the worker who has the same belief as that of CEO in exporting firms, and also increases the aggregate welfare of the economy. By explicitly modeling the optimal effort level decision of individual workers within firms, the model therefore highlights a new source of productivity effects, which could not be captured by previous models in the firm heterogeneity literature where the productivity effect comes mainly from the self-selection (reassignment) of firms (or workers) with exogenously given productivity (or ability) differences.

The rest of the paper is organized as follows. In Section 2, we present the basic setup of the model where heterogeneous workers make an investment decision in acquiring advanced managerial skills and choose their optimal effort level based on their comparative advantage. In Section 3, we study the effects of globalization, and Section 4 supplements our theoretical discussions by exploring numerically a parameterized version of the model. In Section 5, we extend the model to incorporate the externalities between workers' organizational belief and CEO's managerial vision within firms and study the effects of globalization in this case. Section 6 concludes with some concluding remarks.

2. The Model

We consider two symmetric countries. Each country is populated by a unit mass continuum of workers (households), indexed by z. The distribution is given by $G(z)$ with density $g(z)$ on support $[0,\ 1]$. For simplicity of analysis, we assume a uniform distribution. More general distributions could of course be adopted, but that would only complicate the exposition with no additional insights gained. All workers are endowed with one unit of raw input R. Each worker either provides R or can make investments to gain managerial skills, M. Here, R can also be viewed as time of workers, which can be used either to work as production worker or to invest to obtain managerial skills. There are two types of managerial skills to be obtained for two types of strategies, $s \in \{D,\ E\}$: localization (domestic) strategy-specific M_D or internationalization (exporting) strategy-specific M_E.

2.1. Production and Heterogeneous Firms

There is a continuum of firms, each producing a differentiated variety i using natural resources K, and aggregates of labor inputs L. For the sake of simplicity, we assume a Leontief technology for the aggregates of labor inputs. Production of any variety requires combining two labor inputs: α_R units of R and α_M units of M, or equivalently, α_R efficiency units of production workers and α_M efficiency units of non-production managerial workers. These two labor inputs can also be viewed as blue-collar tasks and white-collar tasks that are not substitutable in general. Introducing some substitutability between the two inputs is straightforward, but that would only complicate the analysis with no additional insights gained: all the following results of the paper would be valid insofar as R and M are complementary rather than substitutes. Furthermore, we assume that each firm has access to a fixed amount of natural resources ($\bar{k}$) to produce each variety in the following form:

$$x(i) = min\left(\frac{R(i)}{\alpha_R}, \frac{M(i)}{\alpha_M}\right)\cdot\bar{k}, \quad (1)$$

where $\bar{k} = 1$. For simplicity and without loss of generality, we normalize $\bar{k}$ to one, and focus on the human capital investment of workers at a given amount of natural resources.

Firms are free to enter the market and choose whether or not to engage in international trade. Adopting either strategy incurs strategy-specific fixed costs f_s, $s \in \{D, E\}$, measured in terms of firms' foregone output. Exporting requires higher fixed set-up costs than serving only domestic market; we assume that $f_D < f_E$. Firms are atomistic profit-maximizers and produce goods under monopolistic competition, so that firms charge a constant mark-up over marginal production costs. From the Leontief technology (1), prices are given by:

$$p_s = \frac{\sigma}{\sigma - 1}(\alpha_R w + \alpha_M w_s),\ s \in \{D, E\}, \quad (2)$$

where w and w_s, $s \in \{D, E\}$, are unit production costs of each input (or task-specific efficiency wage rates), and σ is the elasticity of substitution between varieties.

2.2. Technologies and Heterogeneous Workers

One key element of the model is that workers are heterogeneous in their individual ability for each strategy. Workers may have their own preferences and/or subjective beliefs about the likelihood of each strategy dominance in the market, which leads to different career path for skill development. We align workers according to their individual strategy-specific ability. A worker indexed with z has an E-strategy-specific ability level of z, while has a D-strategy-specific ability level of $(1 - z)$; a worker with $z = 1/2$ has the same ability in both strategies and is thus indifferent to both strategies. Note that here we are considering strategy-specific abilities, and not any general managerial skills, that require strategy-specific education and/or training; at a given time constraint, the more workers dedicate their time to obtain one strategy-specific ability, the less they can do for the other ability. Though any more general functional forms can of course be adopted, this mirror-characteristic linear ability schedule is adopted for simplicity. As will be shown later, modeling this two-dimensional ability differentiation allows for the study of the within-firm human capital investment decisions. Additionally, differently from the conventional models in the firm heterogeneity literature in international trade, it is shown that some workers in the domestic firms may have higher wages than some workers in the exporting firms; however, on average exporting firms may pay higher wages as we observe in reality.

There is now ample evidence that exporting firms use more productive technologies than domestic competitors (see, e.g., [31–33] and references therein). There are two strategy-specific technologies v_s, $s \in \{D, E\}$; we assume $v_D < v_E$. Workers then choose firm-types and tasks based on their comparative advantage. The output of a M-worker with an ability level z depends on his/her own effort level e_z for both strategies and the technology used:

$$q_z^s = \varphi_z^s e_z^s,\ s \in \{D, E\}, \quad (3)$$

where φ_z^s is a function of z and v_s, a productivity factor that converts individual effort into respective output of M_D or M_E. Various interpretations might be applicable to the M-workers. One natural interpretation would be middle managers who carry out the strategic directives of CEO at the operational level and supervise the production of R-workers. In this paper we refer to them as managerial workers or simply managers in contrast to production workers. We assume positive externalities between the worker's individual strategy-specific ability and the strategy-specific technology used. Specifically, we assume that:

$$\varphi_z^D = 1 + v_D(1 - z) \text{ and } \varphi_z^E = 1 + v_E z. \quad (4)$$

Equation (4) shows that φ_z^D and φ_z^E monotonically increase in $(1-z)$ and z, as well as in v_D and v_E, respectively. Learning managerial skills requires each strategy-specific individual investment c_s, $s \in \{D,\ E\}$, measured in terms of individual's forgone output. Similarly, we assume that $c_D < c_E$, implying that being an expert for international markets is more costly.

Workers derive utility from net income, and disutility from exerting effort. The utility function is given by:

$$u_z^s = w_s(q_z^s - c_s) - \gamma(e_z^s)^2,\ s \in \{D,\ E\}, \tag{5}$$

where w_s is the respective measured-in-efficiency-units wage rate for $s \in \{D,\ E\}$, and $\gamma > 0$ is a parameter that governs disutility from exerting effort. A utility-maximizing worker z determines his/her optimal level of effort for a given wage rate. From Equations (3)–(5), optimal effort level of a worker z is given by:

$$\begin{aligned} e_z^{Opt} &= \tfrac{w_D[1+v_D(1-z)]}{2\gamma},\ \text{if } s = D, \\ e_z^{Opt} &= \tfrac{w_E[1+v_E z]}{2\gamma},\ \text{if } s = E. \end{aligned} \tag{6}$$

Given this individual optimal level of effort and from Equations (3) and (4), the output of a worker z is then given by:

$$\begin{aligned} q_z^{Opt} &= \tfrac{w_D[1+v_D(1-z)]^2}{2\gamma},\ \text{if } s = D, \\ q_z^{Opt} &= \tfrac{w_E[1+v_E z]^2}{2\gamma},\ \text{if } s = E. \end{aligned} \tag{7}$$

Note from above that e_z^{Opt} and q_z^{Opt} increase in the respective wage rate and the strategy-specific technology, while decrease in γ.

2.3. Self-Selection of Workers

Assuming in what follows that both firm types, D (domestic) and E (exporting), exist in equilibrium, workers will sort based on their respective ability z. Let z_1, z_2 and z_3 be equilibrium thresholds with $0 < z_1 < z_2 < z_3 < 1$. Then, from Equations (3) and (4), workers with low z, $z \in [0,\ z_1]$, would self-select to develop and provide D-specific managerial inputs (M_D), whereas workers with high z, $z \in [z_3,\ 1]$, would self-select to develop and provide E-specific managerial inputs (M_E). The middling workers, $z \in [z_1,\ z_3]$, are relatively indifferent to both strategies, and thus provide their inherently endowed raw inputs R without making any investment to obtain managerial skills. Assuming further that workers having relatively similar abilities work together, workers with $z \in [z_1,\ z_2]$, provide R in domestic firms, while workers with $z \in [z_2,\ z_3]$ provide R in exporting firms. Given that all the workers with $z \in [z_1,\ z_3]$ offer homogeneous R, this distinction has no effect on the main results of the paper, but it serves for the boundary between the two firm-types, as well as corresponds to the widely documented corporate culture literature in the management (see, e.g., [34] and references therein). The middling workers offering homogeneous R get paid the same w in both firm types.

From Equation (7), competitive wage of a worker z net of any learning costs c_s is therefore given by:

$$\begin{aligned} w(z) &= w_D\left[\tfrac{w_D[1+v_D(1-z)]^2}{2\gamma} - c_D\right],\ 0 \le z \le z_1, \\ w(z) &= w,\ z_1 \le z \le z_3, \\ w(z) &= w_E\left[\tfrac{w_E[1+v_E z]^2}{2\gamma} - c_E\right],\ z_3 \le z \le 1, \end{aligned} \tag{8}$$

where we choose w as our numeraire: $w = 1$.

In a perfectly competitive labor market, no-arbitrage conditions for the threshold workers lead to:

$$w_D\left[\frac{w_D[1+v_D(1-z_1)]^2}{2\gamma}-c_D\right]=1, \tag{9}$$

$$w_E\left[\frac{w_E[1+v_E z_3]^2}{2\gamma}-c_E\right]=1, \tag{10}$$

which implicitly pin down z_1 and z_3 as a function of w_D and w_E, respectively, and vice versa. Investigating Equations (9) and (10) leads immediately to the following lemma.

Lemma 1. *A rise(fall) in w_D increases(decreases) the threshold z_1, while a rise(fall) in w_E decreases(increases) the threshold z_3: $\frac{dz_1}{dw_D}>0$ and $\frac{dz_3}{dw_E}<0$.*

Intuitively, higher managerial wages attract more workers to invest and develop managerial skills rather than simply offering their inherently endowed R. More formally, totally differentiating Equation (9), we get $\frac{\mathrm{d}z_1}{\mathrm{d}w_D}=\frac{\gamma(2+c_Dw_D)}{v_Dw_D^3[1+v_D(1-z_1)]}>0$. Similarly, totally differentiating Equation (10), we get $\frac{\mathrm{d}z_3}{\mathrm{d}w_E}=-\frac{\gamma(2+c_Ew_E)}{v_Ew_E^3[1+v_Ez_3]}<0$.

Following Figure 1 illustrates the equilibrium individual wage distribution for different ability levels: the linear representation in Figure 1 is adopted for illustrative purpose only.

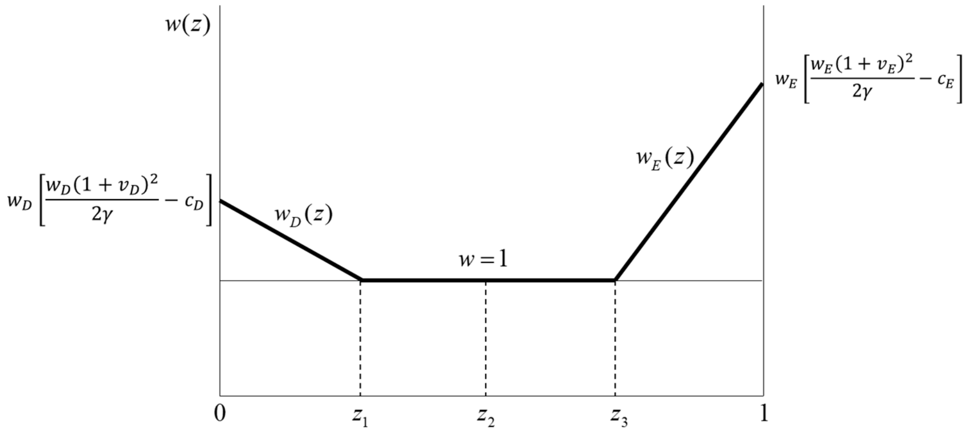

Figure 1. The equilibrium individual wage distribution.

As Figure 1 shows, workers with high z (high E-ability) get paid the most when they work for exporting firms as managerial workers, while workers with low z (high D-ability) get paid the most when they work for domestic firms as managerial workers. The middling workers having relatively indifferent abilities get the highest wage when they work as production workers without making any investment to be a manager. Finally, the outer bold curve in Figure 1 represents the equilibrium individual wage distribution resulting from self-selection of workers based on their individual abilities. Workers with ability $z\in[0, z_2]$ are employed by domestic firms, while workers with ability $z\in[z_2, 1]$ are employed by exporting firms.

2.4. Demand

Households have Dixit–Stiglitz preferences over a continuum of differentiated varieties:

$$C=\left[\int_{i\in N}x(i)^{\frac{\sigma-1}{\sigma}}di\right]^{\frac{\sigma}{\sigma-1}}, \tag{11}$$

where N represents the mass of available varieties, and $\sigma > 1$ is the elasticity of substitution between varieties. Consumer's optimization yields demand schedule for each variety:

$$x(i) = \left(\frac{P_C}{p(i)}\right)^{\sigma} C, \tag{12}$$

associated with an aggregate price index:

$$P_C = \left[\int_{i \in N} p(i)^{1-\sigma} di\right]^{\frac{1}{1-\sigma}}. \tag{13}$$

We assume that exporting goods is associated with iceberg trade costs $\tau > 1$ per unit. The domestic demands for domestically produced and imported goods are then given, respectively, by:

$$x_s^d = \left(\frac{P_C}{p_s}\right)^{\sigma} C, s \in \{D,\ E\},\ \text{and}\ x_m^d = \tau^{1-\sigma}\left(\frac{P_C}{p_E^*}\right)^{\sigma} C, \tag{14}$$

where p_E^* denotes foreign exporters price. In what follows, we use an asterisk to denote foreign variables.

The aggregate consumption price index (13) can be written as:

$$P_C = \left[N_D p_D^{1-\sigma} + N_E p_E^{1-\sigma} + N_E^*(\tau p_E^*)^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \tag{15}$$

where N_D, N_E and N_E^* denote the number of domestic, exporting and foreign exporting firms, respectively, and $N_E = N_E^*$ and $p_E = p_E^*$ from the symmetry.

2.5. Equilibrium

From previously defined z_1, z_2 and z_3, the total supply of R_s, $s \in \{D,\ E\}$, is given by:

$$R_D = \int_{z_1}^{z_2} 1g(z)dz \text{ and } R_E = \int_{z_2}^{z_3} 1g(z)dz, \tag{16}$$

which also can be written simply as $R_D = z_2 - z_1$ and $R_E = z_3 - z_2$ from our uniform distribution assumption. The total supply of M_s, $s \in \{D,\ E\}$, is given, respectively, by:

$$\begin{gathered} M_D = \int_0^{z_1}\left[\frac{w_D[1+v_D(1-z)]^2}{2\gamma} - c_D\right]g(z)dz, \\ M_E = \int_{z_3}^{1}\left[\frac{w_E[1+v_E z]^2}{2\gamma} - c_E\right]g(z)dz. \end{gathered} \tag{17}$$

From the technology (1) and Equations (16) and (17), it follows then that:

$$\frac{1}{\alpha_R}\int_{z_1}^{z_2} 1g(z)dz = \frac{1}{\alpha_M}\int_0^{z_1}\left[\frac{w_D[1+v_D(1-z)]^2}{2\gamma} - c_D\right]g(z)dz, \tag{18}$$

$$\frac{1}{\alpha_R}\int_{z_2}^{z_3} 1g(z)dz = \frac{1}{\alpha_M}\int_{z_3}^{1}\left[\frac{w_E[1+v_E z]^2}{2\gamma} - c_E\right]g(z)dz. \tag{19}$$

Free entry ensures zero profits for both firm types, so that mark-up revenues exactly cover the fixed costs (forgone outputs):

$$\frac{1}{\sigma} p_s x_s = (\alpha_R w + \alpha_M w_s) f_s,\ s \in \{D,\ E\}, \tag{20}$$

where $x_D = x_D^d$ and $x_E = x_E^d + x_m^{d*}$. Now consider the revenue ratio between domestic firms and exporters. From Equations (2), (14) and (20), we have:

$$\left[\frac{\alpha_R w + \alpha_M w_E}{\alpha_R w + \alpha_M w_D}\right] = \left[\frac{f_E}{(1+\tau^{1-\sigma})f_D}\right]^{-\frac{1}{\sigma}}. \tag{21}$$

Here, from the assumption that domestic firms serve only a domestic market (or equivalently, domestic firms exist in equilibrium), it can be easily derived that $w_E < w_D$, implying that $p_E < p_D$ (see Appendix A). Given the presence of both the fixed exporting cost and the iceberg trade cost, entering the export market requires offering their products at cheaper prices than their local competitors to be profitable. Additionally, from our characterization of fixed costs as foregone output and from the technology (1), we have the following equilibrium condition:

$$\frac{1}{\alpha_M} M_s = (x_s + f_s)N_s,\ s \in \{D,\ E\}. \tag{22}$$

Finally, aggregate income follows from factor supplies and prices:

$$Inc = w(R_D + R_E) + w_D M_D + w_E M_E. \tag{23}$$

To sum up, in this model the equilibrium is characterized by five key variables—z_1, z_2, z_3, w_D and w_E—which are determined by five Equations (9), (10), (18), (19) and (21). In the following sections, we therefore focus on how these variables are affected by parameter changes.

3. Globalization

In this section we study the effects of trade liberalization and globalization-induced technological progress.

3.1. Trade Liberalization

We investigate first the impacts of trade liberalization. For this, we begin by studying possible relations between the thresholds (z_1, z_2 and z_3) and w_s, $s \in \{D, E\}$. It can be done by investigating Equations (18) and (19). Consider now a rise in z_1. From Lemma 1 ($\frac{dz_1}{dw_D} > 0$), this increases RHS of Equation (18) unambiguously, which in turn induces a rise in z_2 due to a rise in demand for R in domestic firms. This rise in z_2 decreases LHS of Equation (19) for a given z_3. Then, from Lemma 1 ($\frac{dz_3}{dw_E} < 0$) again, it is straightforward to check that a rise in z_3 is the only possibility to recover the equilibrium condition (19). A fall in z_1 induces inverse effects from the same reasoning. The following lemma establishes.

Lemma 2. *z_1, z_2 and z_3 move in the same direction. And if z_1, z_2 and z_3 increase, w_D rises and w_E falls, while if z_1, z_2 and z_3 decrease, w_D falls and w_E rises.*

We now consider trade liberalization. Trade liberalization can occur either from a fall in τ or from a fall in fixed costs to exporting f_E, both of which induce very similar qualitative effects from Equation (21). One difference lies on the individual firm size adjustments. In this type of monopolistic competition models, changing the marginal costs to exporting (τ) indirectly affects the relative individual firm size from the market competition, while changing firms' fixed costs directly influences the individual firm size. Let us consider a fall in τ. This increases RHS of Equation (21) unambiguously, which in turn induces a rise in $\frac{w_E}{w_D}$ to recover the equilibrium. Then, from Equation (21) and Lemma 2, following proposition establishes immediately.

Propositon 1. *A fall in τ induces a fall in w_D and a rise in w_E, and z_1, z_2 and z_3 decrease.*

From Proposition 1 and Equations (6) and (7), following corollaries follow then immediately.

Corollary 1. *A fall in τ increases the optimal effort level of exporting-firm managerial workers, while decreases that of domestic-firm managerial workers. Consequently, exporting firms' overall productivity increases, while that of domestic firms decreases.*

Corollary 2. *A fall in τ increases between-firm relative managerial incomes in favor of exporting firms; decreases within-firm income inequality in domestic firms, while increases it in exporting firms:* $\frac{d\left(\frac{w_E}{w}\right)}{d\tau} < 0$, $\frac{d\left(\frac{w_D}{w}\right)}{d\tau} > 0$, *and* $\frac{d\left(\frac{w_E}{w_D}\right)}{d\tau} < 0$.

Following Figure 2 illustrates the induced changes in the equilibrium wage distribution.

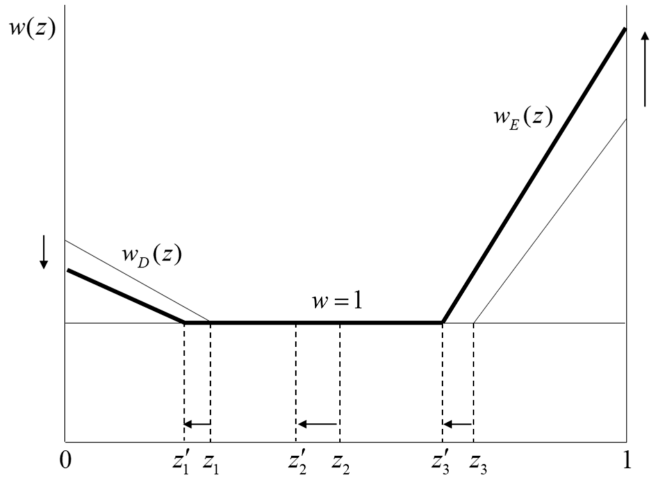

Figure 2. The effects of a fall in τ on the equilibrium wage distribution.

The rise in w_E attracts more workers, $z \in [z_3', z_3]$, to invest in obtaining managerial skills and to become managers in exporting firms, while the fall in w_D induces some managers with relatively low D-ability, $z \in [z_1', z_1]$, to disinvest and turn to production workers in domestic firms. The expansion (compression) of exporting (domestic) firms leads to more (less) employment of production workers in exporting(domestic) firms, so that some production workers previously employed in domestic firms, $z \in [z_2', z_2]$, are now employed by exporting firms.

The impact of a fall in τ on the market concentration can be investigated as follows. From Equations (2), (17), (20) and (22), we have:

$$\begin{aligned} N_D &= \frac{1}{\sigma f_D \alpha_M} \int_0^{z_1} \left[\frac{w_D [1 + v_D(1-z)]^2}{2\gamma} - c_D \right] g(z) dz, \\ N_E &= \frac{1}{\sigma f_E \alpha_M} \int_{z_3}^{1} \left[\frac{w_E [1 + v_E z]^2}{2\gamma} - c_E \right] g(z) dz. \end{aligned} \quad (24)$$

From Proposition 1, following corollary follows immediately.

Corollary 3. *A fall in τ reduces the number of domestic firms (N_D), while increases that of exporting firms (N_E).*

3.2. Technological Progress

It is widely documented that globalization acts also like a technological progress through international knowledge spillovers. Here, we investigate the impacts of an increase in v_E. Note that the analysis is not as simple as before since changes in v_E directly affect the productivity factor in Equation (4) from the externality between workers' ability and the strategy-specific technology, so that now Lemmas 1 and 2 do not hold a priori. The impacts can be investigated in the following steps instead.

First, consider relatively short-run within-exporting-firm impacts. (i) For given employment level and measured-in-efficiency-units wage rate (given z_3 and w_E), the first-order direct impact of a rise in v_E is to increase expected remunerations for managerial workers, which induces a fall in z_3. (ii) Then, to recover the within-firm factor clearing condition (19), w_E starts to decrease and z_3 is shifted back, but finally is situated somewhere below the initial z_3. These changes will then induce between-firm repercussions. From Equation (21), a fall in w_E induces a fall in w_D, which in turn induces a fall in z_1 from Equation (9). The final equilibrium requires overall factors' market clearing conditions (18) and (19). A rise in v_E together with the induced leftward shift of z_3 requires more employment of production workers within exporting firms. On the other hand, a fall in w_D together with leftward shift of z_1 clearly implies less employment of production workers within domestic firms. Finally, from Equations (18) and (19) z_2 should shift left to ensure the overall factors' market clearing. The effects are summarized in the following proposition.

Propositon 2. *A rise in v_E induces falls in w_D and w_E, and leftward shifts of z_1, z_2 and z_3.*

From the positive relationships among the optimal effort level (6), output level (7), and wage schedule of workers (8), following corollaries follow immediately.

Corollary 4. *A rise in v_E increases the optimal effort and output levels of exporting-firm managerial workers, while decreases those of domestic-firm managerial workers.*

Corollary 5. *A rise in v_E increases between-firm relative managerial incomes in favor of exporting firms; decreases within-firm income inequality in domestic firms, while increases it in exporting firms.*

Note that the effects on the measured-in-efficiency-units wages are not the same as the case of trade liberalization. A rise in v_E acts like a technological shock that positively affects the associated workers' productivity. Though a rise in v_E decreases the associated measured-in-efficiency-units wage rate w_E, the final income of managerial workers increases due to the positive productivity effect. A technological progress attracts more workers to invest in obtaining related managerial skills and to become managers within firms, while the opposite occurs within competitors. Additionally, from the above induced changes and from Equation (24), following corollary follows.

Corollary 6. *A rise in v_E increases the number of exporting firms, while reduces the number of domestic firms.*

4. A Numerical Simulation

In this section, we illustrate our theoretical discussions with numerical simulations. The chosen (and/or calibrated) parameter values and initial benchmark equilibrium values for endogenous variables are reported in the Appendix B. The base model parameter values are configured so that initially two firm-types have identical employment size: $z_2 = \frac{1}{2}$, as well as the assumptions made on parameters in the text are satisfied. Initial variable values are normalized to one. Given the initial equilibrium, Appendix C reports the effects of a fall in τ and a rise in v_E, respectively, which confirms our previous theoretical analyses; for a robustness check, simulation results for alternative values of σ are reported.

The concept of sustainable development and growth has been developing over the past decades. Here, we are particularly interested in the aggregate welfare changes. Sustainable development and growth of nations can be defined as sustainable human welfare over time since an economy can be seen as developing in a sustainable way as long as the average individual is not becoming worse off [35,36]. Is this regard, the measure of wealth can also be expanded to include a broadly defined capital that affects the welfare of individuals.

As we have shown, globalization (defined as a fall in τ and/or a rise in v_E) induces an overall human capital accumulation, with more workers investing to obtain high-tech managerial skills.

Following Figures 3 and 4 show how such an accumulation of human capital leads to an improvement of the aggregate welfare, measured as the aggregate real income $\frac{Inc}{P_C}$. Since the total welfare effects may be sensitive to the value of the elasticity of substitution σ in this type of monopolistic competition models, the results are reported for alternative values of σ. Figures 3 and 4 highlight the positive relationship between globalization and sustainable development/growth through globalization-induced human capital accumulation.

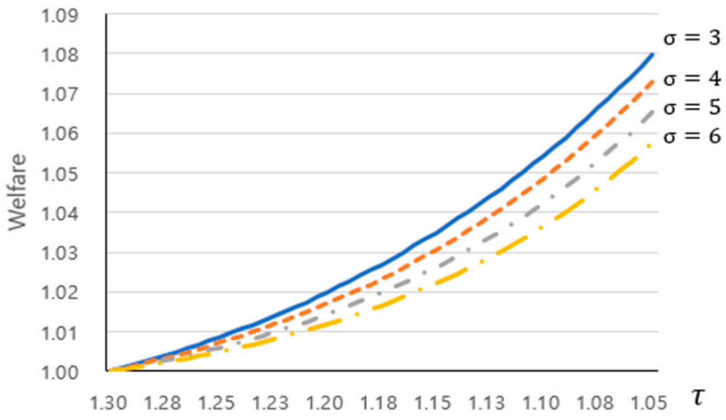

Figure 3. The effects of a fall in τ on welfare.

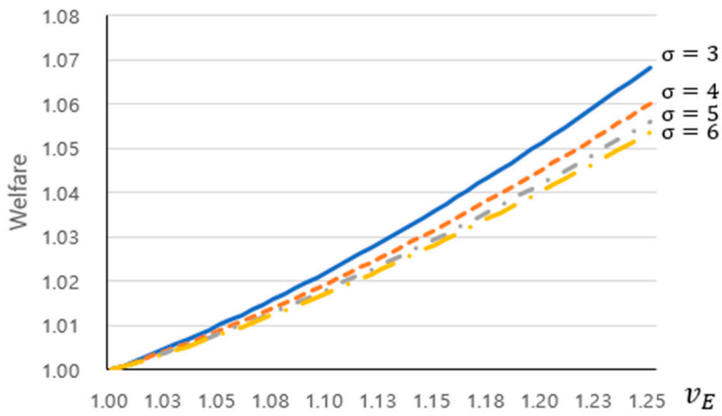

Figure 4. The effects of a rise in v_E on welfare.

Differently from previous models in the firm heterogeneity literature assuming exogenously given productivity and/or ability differences between firms and workers, this paper highlighted the intra-firm human capital investment mechanism where individual workers decide their own effort (and/or investment) levels. We can investigate the welfare implications of such mechanism by comparing current model with fixed individual investment case. Specifically, we fix e_z^s in Equation (3) and compute again the aggregate real income $\frac{Inc}{P_C}$.

As is usual in this type of monopolistic competition model, the aggregate real income (consumption) changes cannot be shown analytically since the number of varieties and prices change simultaneously from Equation (15). On the other hand, the new modeling approach of this paper allows us to investigate the importance of the within-firm human capital investment and accumulation processes. We can compare directly two versions of the model with and without the above-mentioned intra-firm mechanisms.

The two versions of the model (endogenous e_z^s vs. fixed e_z^s) have exactly the same initial parameter and variable values. Following Tables 1 and 2 show the new gains from trade based on endogenous human capital accumulation within firms. For each σ, globalization-induced human capital accumulation leads to significantly higher welfare levels whether we define globalization as a fall in τ or a rise in v_E.

Table 1. The effects of a fall in τ on welfare: endogenous e_z^s vs. fixed e_z^s.

	Endogenous e_z^s				**Fixed e_z^s**			
τ	σ=3	σ=4	σ=5	σ=6	σ=3	σ=4	σ=5	σ=6
1.300	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1.280	1.0031	1.0026	1.0022	1.0018	1.0026	1.0022	1.0018	1.0014
1.260	1.0067	1.0056	1.0046	1.0038	1.0054	1.0045	1.0037	1.0031
1.240	1.0107	1.0090	1.0075	1.0062	1.0086	1.0072	1.0059	1.0049
1.220	1.0151	1.0128	1.0107	1.0089	1.0120	1.0101	1.0084	1.0070
1.200	1.0200	1.0172	1.0144	1.0120	1.0157	1.0134	1.0112	1.0094
1.180	1.0255	1.0220	1.0187	1.0156	1.0199	1.0170	1.0144	1.0121
1.160	1.0316	1.0275	1.0235	1.0198	1.0244	1.0210	1.0179	1.0152
1.140	1.0384	1.0337	1.0290	1.0246	1.0294	1.0255	1.0219	1.0187
1.120	1.0460	1.0408	1.0353	1.0302	1.0348	1.0305	1.0264	1.0227
1.100	1.0544	1.0486	1.0425	1.0366	1.0408	1.0361	1.0315	1.0273
1.080	1.0637	1.0575	1.0507	1.0441	1.0474	1.0423	1.0372	1.0326
1.060	1.0741	1.0675	1.0600	1.0528	1.0546	1.0492	1.0437	1.0386

Table 2. The effects of a rise in v_E on welfare: endogenous e_z^s vs. fixed e_z^s.

	Endogenous e_z^s				**Fixed e_z^s**			
v_E	σ=3	σ=4	σ=5	σ=6	σ=3	σ=4	σ=5	σ=6
1.000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1.020	1.0038	1.0034	1.0031	1.0030	1.0035	1.0031	1.0028	1.0027
1.040	1.0079	1.0070	1.0065	1.0062	1.0072	1.0062	1.0058	1.0055
1.060	1.0124	1.0109	1.0102	1.0097	1.0109	1.0095	1.0088	1.0084
1.080	1.0172	1.0151	1.0140	1.0135	1.0148	1.0129	1.0120	1.0114
1.100	1.0222	1.0195	1.0182	1.0174	1.0188	1.0164	1.0152	1.0145
1.120	1.0275	1.0242	1.0226	1.0216	1.0230	1.0199	1.0185	1.0177
1.140	1.0331	1.0291	1.0272	1.0260	1.0272	1.0236	1.0219	1.0209
1.160	1.0389	1.0343	1.0320	1.0307	1.0315	1.0273	1.0254	1.0243
1.180	1.0450	1.0397	1.0370	1.0355	1.0359	1.0312	1.0289	1.0277
1.200	1.0514	1.0452	1.0422	1.0404	1.0404	1.0351	1.0326	1.0312
1.220	1.0580	1.0511	1.0476	1.0456	1.0450	1.0391	1.0363	1.0347
1.240	1.0648	1.0571	1.0532	1.0510	1.0497	1.0431	1.0400	1.0384

5. Organizational Belief and Managerial Vision

Before concluding, in this section we discuss possible implications of workers' organizational belief and CEO's managerial vision within firms. Our analyses so far have been based on exogenously given workers' initial ability levels and did not explain what determines such ability differences. One widely accepted explanation in the business and management literature would be the externality between workers' organizational beliefs and the CEO's managerial vision (see, e.g., [37] and references therein). Workers decide to invest and make efforts based on their own organizational belief and the CEO's managerial vision. Suppose now that all workers have their own subjective belief about the likelihood of each strategy dominance in the market: a worker z believes with probability z that the dominant overall market (and/or organization he/she works for) strategy would be E, while believes with probability $(1-z)$ that D would be dominant. Due to be the positive externalities, workers having similar organizational beliefs to the CEO's managerial vison have higher ability levels in the organization. Previous base model can easily be extended to incorporate explicitly such externalities. We now assume that:

$$\varphi_z^D = a_D - (v_D - z)^2 \text{ and } \varphi_z^E = a_E - (v_E - z)^2, \tag{25}$$

where z is the individual organizational belief and v_D and v_E are CEO's managerial vision for localization and internationalization, respectively, with $v_E > v_D$. Why CEOs have a different vision is out of the scope of this paper, but it is widely documented that firm policies and/or strategies systematically depend on the identity of the CEO [38]. Following the previous definition, high z implies high belief (preference) for E-strategy, while low z implies high belief (preference) for D-strategy. However, note that here v_E is not necessarily higher than the highest z, as well as that v_D is not necessarily lower than the lowest z. Thus, in Equation (25) a_D and a_E are parameters representing the maximum productivity of a worker who has the same belief as that of CEO in domestic and exporting firms, respectively. We assume that $a_E > a_D$ given the higher learning cost to obtain export market managerial skills: $c_E > c_D$. Replacing these in Equation (5), optimal effort level of a worker z is now given by:

$$\begin{aligned} e_z^{Opt} &= \frac{w_D\left[a_D-(v_D-z)^2\right]}{2\gamma}, \text{ if } s = D, \\ e_z^{Opt} &= \frac{w_E\left[a_E-(v_E-z)^2\right]}{2\gamma}, \text{ if } s = E, \end{aligned} \tag{26}$$

and the output of a worker z is given by:

$$\begin{aligned} q_z^{Opt} &= \frac{w_D\left[a_D-(v_D-z)^2\right]^2}{2\gamma}, \text{ if } s = D, \\ q_z^{Opt} &= \frac{w_E\left[a_E-(v_E-z)^2\right]^2}{2\gamma}, \text{ if } s = E. \end{aligned} \tag{27}$$

Note from above that, unlike the previous model e_z^{Opt} and q_z^{Opt} now increase in the similarity between z and v_s, $s \in \{D,\ E\}$. From above, the modified wage schedules are given by:

$$\begin{aligned} w(z) &= w_D\left[\frac{w_D\left[a_D-(v_D-z)^2\right]^2}{2\gamma} - c_D\right],\ 0 \le z \le z_1, \\ w(z) &= w,\ z_1 \le z \le z_3, \\ w(z) &= w_E\left[\frac{w_E\left[a_E-(v_E-z)^2\right]^2}{2\gamma} - c_E\right],\ z_3 \le z \le 1. \end{aligned} \tag{28}$$

Previous no-arbitrage conditions (9) and (10), and supply Equation (17) are modified accordingly to:

$$w_D\left[\frac{w_D\left[a_D-(v_D-z_1)^2\right]^2}{2\gamma} - c_D\right] = 1, \tag{29}$$

$$w_E\left[\frac{w_E\left[a_E-(v_E-z_3)^2\right]^2}{2\gamma} - c_E\right] = 1, \tag{30}$$

and

$$\begin{aligned} M_D &= \int_0^{z_1}\left[\frac{w_D\left[a_D-(v_D-z)^2\right]^2}{2\gamma} - c_D\right]g(z)dz, \\ M_E &= \int_{z_3}^{1}\left[\frac{w_E\left[a_E-(v_E-z)^2\right]^2}{2\gamma} - c_E\right]g(z)dz, \end{aligned} \tag{31}$$

from which factor clearing conditions (18) and (19) are also modified accordingly to:

$$\frac{1}{\alpha_R}\int_{z_1}^{z_2} 1g(z)dz = \frac{1}{\alpha_M}\int_0^{z_1}\left[\frac{w_D\left[a_D-(v_D-z)^2\right]^2}{2\gamma}-c_D\right]g(z)dz, \tag{32}$$

$$\frac{1}{\alpha_R}\int_{z_2}^{z_3} 1g(z)dz = \frac{1}{\alpha_M}\int_{z_3}^{1}\left[\frac{w_E\left[a_E-(v_E-z)^2\right]^2}{2\gamma}-c_E\right]g(z)dz. \tag{33}$$

As before, the equilibrium is characterized by five key variables—z_1, z_2, z_3, w_D and w_E—, which are determined accordingly in this case by five Equations (21), (29), (30), (32) and (33). Note, however, from Equations (29) and (30) that in this case the initial v_D and v_E relative to workers' overall beliefs matter. If initially $v_D < z_1$ and $v_E > z_3$, we have $\frac{dw_D}{dz_1} > 0$ and $\frac{dw_E}{dz_3} < 0$. Though much less plausible, however, if initially $v_D > z_1$ and $v_E < z_3$, we would have $\frac{dw_D}{dz_1} < 0$ and $\frac{dw_E}{dz_3} > 0$. More formally, totally differentiating Equation (29), we get $\frac{dw_D}{dz_1} = -\frac{2w_D^3\left[a_D-(v_D-z_1)^2\right](v_D-z_1)}{\gamma(2+c_Dw_D)}$, which is negative (positive) if $v_D > z_1(v_D < z_1)$. Similarly, totally differentiating Equation (30), we get $\frac{dw_E}{dz_3} = -\frac{2w_E^3\left[a_E-(v_E-z_3)^2\right](v_E-z_3)}{\gamma(2+c_Ew_E)}$, which is negative (positive) if $v_E > z_3(v_E < z_3)$. Following Figure 5 illustrates the modified equilibrium wage distribution for the former case. Here, we do not explicitly model the earnings of CEOs for expositional simplicity purpose. However, it is straightforward to adapt the formulation: one convenient and widely used modeling approach is to assume that the firms' operating profits (the fixed costs in this model) go to the CEOs (see, e.g., [39] and references therein).

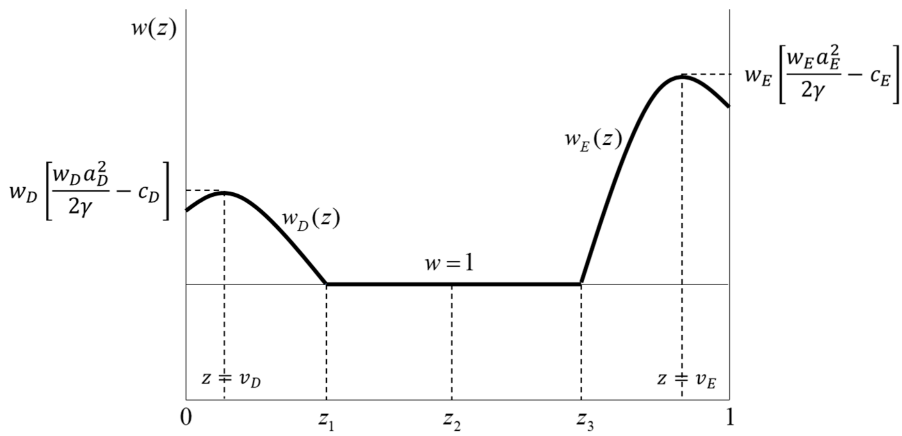

Figure 5. The equilibrium individual wage distribution when $\varphi_z^s = a_s - (v_s - z)^2, s \in \{D, E\}$.

Thus, in this case it is the worker with the same belief as CEO's managerial vision who earns the highest income in each firm-type. Additionally, the presence of fixed learning costs to obtain managerial skills requires higher remunerations justifying such investments. Note that the sufficient condition for all managerial workers to get higher income than production workers is that initially v_E and v_D are stronger than the median belief of managerial workers in each firm-type, i.e., $v_E > \frac{(z_3+1)}{2}$ and $v_D < \frac{z_1}{2}$: this condition rules out also the case where the wage distribution cuts the horizontal line again on the extreme left and on the extreme right in Figure 5. From the definition of visionary CEO, we focus on what follows on such cases.

It follows then immediately that Lemma 2 applies in this case too from the same reasoning as before. It can also be checked easily that globalization (a fall in τ) induces the same effects as before. A fall in τ induces a fall in w_D and a rise in w_E, and z_1, z_2 and z_3 shift leftward. Following Figure 6 illustrates the effects of a fall in τ in this case.

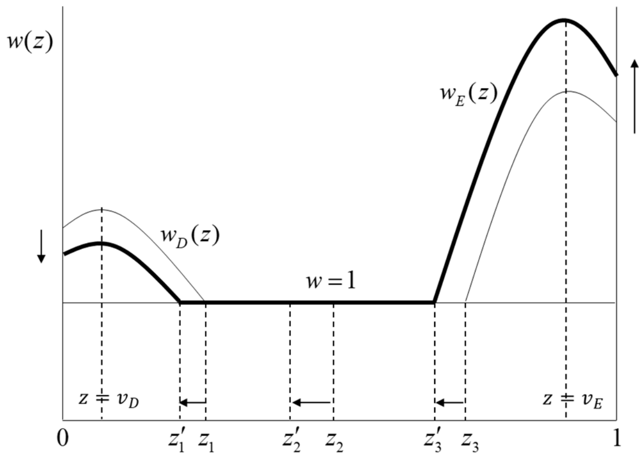

Figure 6. The effects of a fall in τ when $\varphi_z^s = a_s - (v_s - z)^2$, $s \in \{D,\ E\}$.

Note, however, that in this case within-firm income implications are different from before. It is now the worker with $z = v_E$ whose income increases the most following a fall in τ, while it is the worker with $z = v_D$ in domestic firms whose income decreases the most. It may be due to the presence of fixed learning cost c_s, $s \in \{D,\ E\}$. A rise in w_E due to a fall in τ increases also the learning cost in nominal term. Additionally, this comes as a relatively less burden to the workers having similar beliefs as that of CEO since initially the proportion of learning cost in their total income is relatively small. Similarly, a fall in w_D due to a fall in τ decreases also the learning cost in nominal term in domestic firms; this beneficial effect is relatively small to the workers having similar beliefs as that of CEO since initially the proportion of learning cost in their total income is relatively small. Consequently, the overall negative impact from a fall in w_D affects the most negatively the worker with $z = v_D$.

Following Figure 7 shows the welfare effects of globalization for alternative values of σ under positive externality between workers' organizational belief and CEO's managerial vision. In this case too, the globalization-induced human capital accumulation leads to significant welfare improvements.

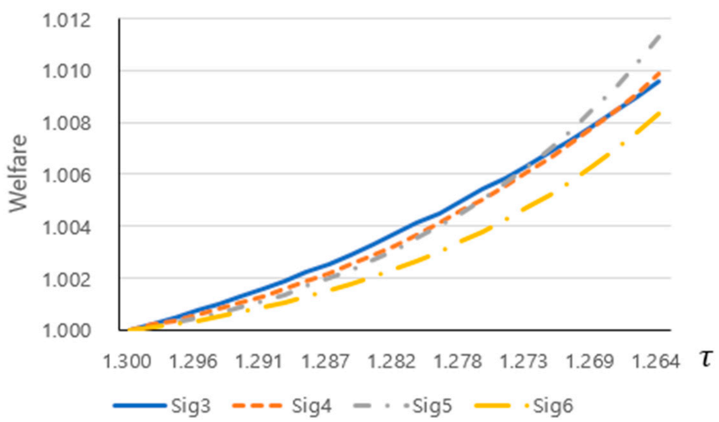

Figure 7. The effects of a fall in τ on welfare when $\varphi_z^s = a_s - (v_s - z)^2$, $s \in \{D,\ E\}$.

6. Conclusions

It has been widely documented in the management literature that the organizational behavior and human decision processes within firms have important implications for the firm's behavior and performance. Though recent firm heterogeneity literature in international trade has made substantial advances in highlighting many systematic links between the characteristics of firms and their degree of internationalization, as well as bringing many important trade policy implications at the aggregate level, much less attention has been paid to the within-firm managerial mechanisms and the resulting strategic direction and performance of firms.

This paper made a first attempt to bridge the gap by developing a general-equilibrium trade model in which heterogeneous employees make an investment decision in acquiring advanced managerial skills and choose their optimal effort level based on their own comparative advantage. By explicitly modeling the optimal effort level decision of individual workers, as well as the individual investment decision to obtain advanced managerial skills, we highlighted how globalization may induce human capital accumulation within firms and contribute to achieve sustainable economic growth at a given amount of natural resources. We also highlighted that workers' organizational belief and CEO's managerial vision may be an important element for the human capital formation within firms and for the performance of firms in a global economy.

Though it was not the focus of this paper, the model highlights implicitly the importance of the labor market flexibility in a broad sense. We have assumed a perfectly competitive labor market, but the adjustments of the thresholds (z_1, z_2 and z_3) would largely be dependent on the working of the local market. Economies having low institutional quality will experience rigid adjustments of the thresholds, which will inevitably lead to human–technology misallocation and/or unemployment. Thus, overall institutional-quality improvement of the local market might be as important as any other technological innovations to increase aggregate productivity.

At least in this model's context, it should be clear that the intra-firm managerial mechanisms and the resulting strategic direction and performance of firms determine the size and direction of the aggregate effects of any policy changes. As the model shows, among others, the interaction between workers' organizational belief and CEO's managerial vision might be as important factor as tariff reduction movements to enhance international trade. Needless to say, the model abstracts from other important issues of the real world such as various labor market imperfections and the model's theoretical predictions need to be tested in various ways. I believe that this paper's attempt opens up new avenues for various promising extensions and for future research.

Various practical issues related to the operational research would be of great interest. Currently, we have assumed the same (exogenously given) strategy-specific individual investment cost (c_s) paid by each worker. Though the main qualitative insights of the model would not be affected, considering heterogeneous individual costs as well as the different sources of the investment might lead to different quantitative results through various internal incentive mechanisms. Additionally, the current developed model may be incorporated into large-scale computable general equilibrium (CGE) models to examine various policy implications. I leave them for future research.

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Appendix A

Suppose potential revenue of D-firms, y_D^*, if they would engage in international trade too after paying the fixed cost to exporting f_E. The fact that domestic firms serve only the domestic market implies that the potential mark-up revenue from exporting does not cover the necessary fixed costs: $\frac{1}{\sigma}y_D^* < (\alpha_R w + \alpha_M w_D) f_E$. Now consider the revenue ratio between exporting E-firms and these potential D-firms. From Equations (7), (14) and

(20), and now by substituting $x_D^* = x_D^d + x_{m,D}^{d*}$ and f_E for x_D and f_D, respectively, we get $\frac{\sigma y_E}{\sigma y_D^*} = \left(\frac{\alpha_R w + \alpha_M w_E}{\alpha_R w + \alpha_M w_D}\right)^{1-\sigma}$, while the fixed cost ratio is given by $\frac{(\alpha_R w + \alpha_M w_E) f_E}{(\alpha_R w + \alpha_M w_D) f_E}$. Now we have $\left(\frac{\alpha_R w + \alpha_M w_E}{\alpha_R w + \alpha_M w_D}\right)^{1-\sigma} > \frac{(\alpha_R w + \alpha_M w_E) f_E}{(\alpha_R w + \alpha_M w_D) f_E}$ since $\frac{1}{\sigma} y_D^* < (\alpha_R w + \alpha_M w_D) f_E$. Arranging this leads to $\frac{\alpha_R w + \alpha_M w_E}{\alpha_R w + \alpha_M w_D} < 1$, which implies that $w_E < w_D$ and $p_E < p_D$. Note, however, that this does not imply that workers in exporting firms get paid lower wages: as in Equations (7) and (8), workers are paid based on their respective outputs. Though it is straightforward to derive explicit conditions that average wage is higher in exporting firms as the evidence shows, here we do not need such conditions for the main results of the paper.

Appendix B

Benchmark Parameter and Variable Values

Table A1. Benchmark parameter and variable values.

σ	τ	c_D	c_E	γ	v_D	v_E	f_D	f_E	α_R	α_M
3.00	1.30	0.10	0.20	1.00	1.10	1.39	1.00	1.80	1.00	1.00
C	P_C	x_D^d	x_E^d	x_m^d	x_D	x_E	w	w_D	w_E	R_D
0.18	6.02	2.00	2.26	1.34	2.00	3.60	1.00	0.78	0.71	0.30
R_E	M_D	M_E	z_1	z_2	z_3	N_D	N_E	p_D	p_E	Inc
0.31	0.30	0.31	0.20	0.50	0.81	0.10	0.06	2.68	2.57	1.06

Appendix C

The Effects of Globalization for Alternative Values of σ

Table A2. The effects of falls in τ when $\sigma = 3$.

τ	P_C	w_D	w_E	M_D	M_E	z_1	z_2	z_3	N_D	N_E	Inc
1.300	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.280	0.997	0.996	1.005	0.964	1.036	0.965	0.964	0.964	0.964	1.036	1.000
1.260	0.994	0.991	1.010	0.927	1.073	0.928	0.927	0.927	0.927	1.073	1.001
1.240	0.991	0.987	1.015	0.889	1.112	0.890	0.889	0.889	0.889	1.112	1.001
1.220	0.987	0.982	1.020	0.849	1.152	0.851	0.850	0.849	0.849	1.152	1.002
1.200	0.983	0.977	1.026	0.808	1.193	0.810	0.809	0.808	0.808	1.193	1.003
1.180	0.979	0.972	1.032	0.765	1.236	0.768	0.766	0.765	0.765	1.236	1.004
1.160	0.975	0.967	1.038	0.721	1.281	0.724	0.722	0.721	0.721	1.281	1.006
1.140	0.971	0.962	1.044	0.675	1.327	0.678	0.676	0.675	0.675	1.327	1.008
1.120	0.966	0.956	1.051	0.628	1.376	0.631	0.629	0.628	0.628	1.376	1.011
1.100	0.961	0.951	1.058	0.578	1.426	0.581	0.580	0.578	0.578	1.426	1.013
1.080	0.956	0.945	1.066	0.527	1.478	0.530	0.528	0.527	0.527	1.478	1.017
1.060	0.950	0.939	1.073	0.474	1.532	0.477	0.475	0.474	0.474	1.532	1.021

Table A3. The effects of falls in τ when $\sigma = 4$.

τ	P_C	w_D	w_E	M_D	M_E	z_1	z_2	z_3	N_D	N_E	*Inc*
1.300	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.280	0.998	0.996	1.005	0.966	1.034	0.966	0.966	0.992	0.966	1.034	1.000
1.260	0.995	0.991	1.009	0.930	1.071	0.930	0.930	0.984	0.930	1.071	1.000
1.240	0.992	0.987	1.014	0.892	1.109	0.893	0.892	0.975	0.892	1.109	1.001
1.220	0.989	0.982	1.020	0.852	1.149	0.854	0.853	0.966	0.852	1.148	1.002
1.200	0.986	0.977	1.025	0.811	1.190	0.813	0.811	0.957	0.811	1.190	1.003
1.180	0.982	0.972	1.031	0.767	1.234	0.769	0.768	0.947	0.767	1.234	1.004
1.160	0.979	0.967	1.038	0.721	1.281	0.724	0.722	0.937	0.721	1.280	1.006
1.140	0.975	0.961	1.045	0.673	1.329	0.676	0.675	0.926	0.673	1.329	1.008
1.120	0.971	0.956	1.052	0.623	1.380	0.626	0.624	0.915	0.623	1.380	1.010
1.100	0.966	0.950	1.059	0.570	1.434	0.573	0.572	0.903	0.570	1.433	1.013
1.080	0.962	0.943	1.067	0.515	1.490	0.518	0.516	0.891	0.515	1.490	1.017
1.060	0.957	0.937	1.076	0.457	1.549	0.460	0.458	0.878	0.457	1.549	1.021

Table A4. The effects of falls in τ when $\sigma = 5$.

τ	P_C	w_D	w_E	M_D	M_E	z_1	z_2	z_3	N_D	N_E	*Inc*
1.300	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.280	0.998	0.996	1.004	0.969	1.031	0.970	0.969	0.993	0.969	1.031	1.000
1.260	0.996	0.992	1.008	0.937	1.064	0.937	0.937	0.986	0.937	1.064	1.000
1.240	0.993	0.988	1.013	0.902	1.098	0.903	0.902	0.978	0.902	1.098	1.001
1.220	0.991	0.984	1.018	0.865	1.136	0.867	0.866	0.970	0.865	1.136	1.001
1.200	0.988	0.979	1.023	0.826	1.175	0.828	0.827	0.961	0.826	1.175	1.002
1.180	0.985	0.974	1.029	0.784	1.217	0.786	0.785	0.951	0.784	1.217	1.003
1.160	0.982	0.969	1.035	0.740	1.262	0.742	0.741	0.942	0.740	1.262	1.005
1.140	0.978	0.964	1.042	0.693	1.309	0.695	0.694	0.931	0.693	1.310	1.007
1.120	0.975	0.958	1.049	0.643	1.360	0.646	0.644	0.920	0.643	1.360	1.009
1.100	0.971	0.952	1.057	0.590	1.414	0.593	0.591	0.908	0.590	1.414	1.012
1.080	0.966	0.945	1.065	0.533	1.471	0.536	0.534	0.895	0.533	1.471	1.015
1.060	0.962	0.939	1.074	0.473	1.533	0.476	0.474	0.882	0.473	1.533	1.020

Table A5. The effects of falls in τ when $\sigma = 6$.

τ	P_C	w_D	w_E	M_D	M_E	z_1	z_2	z_3	N_D	N_E	*Inc*
1.300	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.280	0.998	0.997	1.003	0.974	1.026	0.974	0.974	0.994	0.974	1.027	1.000
1.260	0.996	0.993	1.007	0.945	1.055	0.946	0.945	0.988	0.945	1.055	1.000
1.240	0.994	0.990	1.011	0.914	1.086	0.915	0.915	0.981	0.914	1.086	1.001
1.220	0.992	0.986	1.016	0.881	1.119	0.883	0.882	0.973	0.881	1.119	1.001
1.200	0.990	0.981	1.021	0.845	1.155	0.847	0.846	0.965	0.845	1.155	1.002
1.180	0.987	0.977	1.026	0.807	1.194	0.809	0.808	0.957	0.807	1.194	1.003
1.160	0.984	0.972	1.032	0.765	1.236	0.768	0.766	0.947	0.765	1.236	1.004
1.140	0.981	0.967	1.038	0.720	1.281	0.723	0.722	0.937	0.720	1.282	1.006
1.120	0.978	0.961	1.045	0.672	1.330	0.675	0.673	0.927	0.672	1.330	1.008
1.100	0.974	0.955	1.052	0.620	1.383	0.623	0.621	0.915	0.620	1.383	1.010
1.080	0.971	0.949	1.060	0.564	1.440	0.567	0.566	0.903	0.564	1.440	1.013
1.060	0.966	0.942	1.069	0.504	1.501	0.507	0.505	0.889	0.504	1.501	1.017

Table A6. The effects of rises in v_E when $\sigma = 3$.

v_E	P_C	w_D	w_E	M_D	M_E	z_1	z_2	z_3	N_D	N_E	*Inc*
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.020	0.996	0.994	0.994	0.953	1.052	0.954	0.953	0.991	0.953	1.052	1.000
1.040	0.992	0.989	0.988	0.907	1.104	0.908	0.907	0.982	0.907	1.104	1.000
1.060	0.989	0.983	0.982	0.861	1.156	0.862	0.861	0.974	0.861	1.156	1.001
1.080	0.985	0.978	0.977	0.815	1.207	0.817	0.816	0.965	0.815	1.207	1.002
1.100	0.981	0.972	0.971	0.770	1.259	0.772	0.771	0.957	0.770	1.259	1.002
1.120	0.977	0.967	0.965	0.725	1.310	0.728	0.727	0.949	0.725	1.310	1.004
1.140	0.973	0.962	0.960	0.681	1.362	0.684	0.682	0.942	0.681	1.362	1.005
1.160	0.969	0.957	0.955	0.637	1.413	0.640	0.639	0.934	0.637	1.413	1.007
1.180	0.965	0.952	0.950	0.594	1.465	0.597	0.595	0.927	0.594	1.465	1.008
1.200	0.961	0.947	0.944	0.551	1.516	0.554	0.552	0.920	0.551	1.516	1.010
1.220	0.957	0.943	0.939	0.508	1.568	0.511	0.509	0.913	0.508	1.568	1.012
1.240	0.953	0.938	0.935	0.466	1.619	0.468	0.467	0.907	0.466	1.619	1.014

Table A7. The effects of rises in v_E when $\sigma = 4$.

v_E	P_C	w_D	w_E	M_D	M_E	z_1	z_2	z_3	N_D	N_E	*Inc*
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.020	0.997	0.994	0.994	0.952	1.053	0.953	0.953	0.991	0.952	1.053	1.000
1.040	0.993	0.989	0.988	0.905	1.105	0.906	0.906	0.982	0.905	1.105	1.000
1.060	0.990	0.983	0.982	0.859	1.158	0.860	0.859	0.974	0.859	1.157	1.001
1.080	0.986	0.977	0.976	0.812	1.210	0.814	0.813	0.966	0.812	1.210	1.001
1.100	0.983	0.972	0.970	0.767	1.262	0.769	0.768	0.958	0.767	1.262	1.002
1.120	0.980	0.967	0.964	0.721	1.314	0.724	0.722	0.950	0.721	1.314	1.003
1.140	0.976	0.962	0.959	0.677	1.367	0.679	0.678	0.943	0.677	1.367	1.005
1.160	0.973	0.957	0.953	0.632	1.419	0.635	0.633	0.935	0.632	1.419	1.006
1.180	0.969	0.952	0.948	0.588	1.471	0.591	0.589	0.928	0.588	1.471	1.008
1.200	0.966	0.947	0.943	0.544	1.523	0.547	0.545	0.921	0.544	1.523	1.010
1.220	0.962	0.942	0.938	0.501	1.575	0.503	0.502	0.914	0.500	1.575	1.012
1.240	0.959	0.937	0.932	0.457	1.627	0.460	0.459	0.908	0.457	1.627	1.014

Table A8. The effects of rises in v_E when $\sigma = 5$.

v_E	P_C	w_D	w_E	M_D	M_E	z_1	z_2	z_3	N_D	N_E	*Inc*
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.020	0.997	0.994	0.994	0.952	1.053	0.953	0.952	0.991	0.952	1.053	1.000
1.040	0.994	0.988	0.988	0.905	1.106	0.906	0.905	0.982	0.905	1.106	1.000
1.060	0.990	0.983	0.981	0.858	1.158	0.860	0.859	0.974	0.858	1.158	1.001
1.080	0.987	0.977	0.976	0.812	1.211	0.814	0.812	0.966	0.812	1.211	1.001
1.100	0.984	0.972	0.970	0.766	1.263	0.768	0.767	0.958	0.766	1.263	1.002
1.120	0.981	0.967	0.964	0.720	1.316	0.723	0.721	0.950	0.720	1.316	1.003
1.140	0.978	0.961	0.958	0.675	1.368	0.678	0.676	0.943	0.675	1.368	1.004
1.160	0.975	0.956	0.953	0.630	1.421	0.633	0.631	0.935	0.630	1.421	1.006
1.180	0.972	0.951	0.947	0.586	1.473	0.589	0.587	0.928	0.586	1.473	1.007
1.200	0.968	0.946	0.942	0.542	1.525	0.545	0.543	0.921	0.542	1.525	1.009
1.220	0.965	0.942	0.937	0.498	1.578	0.501	0.499	0.915	0.498	1.578	1.011
1.240	0.962	0.937	0.932	0.455	1.630	0.457	0.456	0.908	0.455	1.630	1.013

Table A9. The effects of rises in v_E when $\sigma = 6$.

v_E	P_C	w_D	w_E	M_D	M_E	z_1	z_2	z_3	N_D	N_E	*Inc*
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.020	0.997	0.994	0.994	0.952	1.053	0.953	0.952	0.991	0.952	1.053	1.000
1.040	0.994	0.988	0.987	0.905	1.106	0.906	0.905	0.982	0.905	1.106	1.000
1.060	0.991	0.983	0.981	0.858	1.158	0.859	0.858	0.974	0.858	1.158	1.001
1.080	0.988	0.977	0.975	0.811	1.211	0.813	0.812	0.966	0.811	1.211	1.001
1.100	0.985	0.972	0.970	0.765	1.264	0.768	0.766	0.958	0.765	1.264	1.002
1.120	0.982	0.967	0.964	0.720	1.316	0.722	0.721	0.950	0.720	1.316	1.003
1.140	0.979	0.961	0.958	0.675	1.369	0.677	0.676	0.943	0.675	1.369	1.004
1.160	0.976	0.956	0.953	0.630	1.421	0.633	0.631	0.936	0.630	1.421	1.006
1.180	0.973	0.951	0.947	0.585	1.473	0.588	0.587	0.928	0.585	1.473	1.007
1.200	0.970	0.946	0.942	0.541	1.526	0.544	0.542	0.922	0.541	1.526	1.009
1.220	0.967	0.942	0.937	0.497	1.578	0.500	0.499	0.915	0.498	1.578	1.011
1.240	0.964	0.937	0.932	0.454	1.630	0.457	0.455	0.908	0.454	1.631	1.013

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