Quality Goods, Trade liberalization and Wage Inequality

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1 Introduction

This paper constructs what I can call the *Chinese model* of quality good trade. At the present time, China has the following feature: importing high quality cars, producing low quality cars that are consumed domestically, and importing some parts for producing low quality cars. The model of this paper captures this structure of the Chinese economy. Using this model, I analyze the impact of trade liberalization on wage inequality in such a developing country.

In this study, tariff reduction takes place as trade liberalization. Since China entered the WTO in 2004, she has experienced a continuous tariff reduction on automobiles. The tariff on passenger cars is reduced from 80% in 2002 to 28% in 2006 and the tariff on parts is reduced from 50% in 2002 to 10% in 2006. Reflecting on the structure of the Chinese economy, I introduce two types of tariff on imports into the model: a tariff on high quality goods and a tariff on parts of low quality goods. This study shows that when tariffs are reduced, the two types of tariff have completely different effects on wage inequality.

In China, low quality cars are produced by joint ventures. For example, Guangzhou-Honda is the joint venture of a local firm with Honda in Japan and is importing some parts from Japan, i.e., it engages in fragmentation/outsourcing. My paper captures this phenomenon by introducing imports of intermediate goods into the model. In the existing literature on wage inequality, there are some studies that highlight fragmentation/outsourcing. For example, in Feenstra and Hanson (1996), it is international capital movement that affects wage inequality. In Marjit, Beladi and Chakrabarti (2004),

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it is the occurrence of fragmentation that affects wage inequality. In this paper, it is tariff reduction that affects wage inequality.

Since automobiles in China can be regarded as quality goods, I employ the framework of Flam and Helpman (1987) of quality good trade. In their paper, wage inequality within a country is exogenously fixed. By contrast, in this paper, this wage inequality is endogenously determined, so that I can analyze how tariff reduction affects the wage inequality. Xu (2003) also builds a model in which tariff reduction affects the wage inequality. However, he focuses on horizontally differentiated products, while I focus on vertically differentiated products.

In an advanced group of developing countries such as China, a manufacturing sector can be divided into an ordinary manufacturing sector and a more modern manufacturing sector. My model contains these two manufacturing sectors and treats the more modern manufacturing sector as a quality good sector.

It can be observed that goods in a modern manufacturing sector in a developing country are not exported to the world market and sold in the domestic market under tariff protection, as in China. This characteristic is considered in this paper in the way that quality goods produced domestically are nontradeable. Acharyya and Jones (2001) build a small country model in which quality goods produced domestically are exportable. In this paper, these goods are nontradeable.

The model is developed in section 2. In section 3, I focus on the labor market to derive the demand curve and the supply curve of skilled labor in quality goods sector to analyze the equilibrium wage. The implications of trade liberalizations are examined in section 4. Section 5 is the conclusion.

2 The Model

It is assumed that two commodities exist in a small open country (home country): a homogeneous product A, and a quality-differentiated product Q. Quality is observable to all and is indexed by z. Larger values of z represent higher quality.

There are three factors of production in the home country: unskilled labor (L), specific to production of good A; imported intermediate good M, specific to production of quality-differentiated product Q and skilled labor (S) used by both sectors. Intermediate good M is introduced to reflect the import-dependent production feature in China and the tariff on it will allow us to investigate some implications of trade liberalization in intermediate goods.

The sector of product A is perfectly competitive and its technology is of constant returns to scale. Let w_L and w_S be the wage rates of unskilled and skilled workers, respectively. Suppose that w_S is larger than w_L. The profit maximization of product A implies

$$w_L a_{LA}(w_L, w_S) + w_S a_{SA}(w_L, w_S) = p_A, \tag{1}$$

where p_A represents the world price of A, which is assumed to be unity. The cost-minimizing input coefficient $a_{iA} \equiv a_{iA}(w_L, w_S)$ indicates the amount of input i $(i = L, S)$ required to produce one unit of A.

The technology of product Q in the home country is in a lower level compared to foreign countries. That is, for any given z, the average cost of product Q in the home country is higher than its world price. But some quality varieties can be produced in the home country due to the tariffs on foreign quality goods. For simplicity, assume an identical ad valorem tariff rate t_Q to be imposed on all foreign quality goods. This allows us to examine some implications of trade liberalization in final goods.

The sector of product Q is perfectly competitive and for any given quality z, skilled labor and intermediate good M are used in fixed proportions in production. But, the production technology is such that higher-quality varieties employ more of skilled labor and intermediate good M relative to lower-quality goods. In addition, we have diminishing return to skilled labor and intermediate good M (with respect to quality). The unit cost, $H(z)$, is expressed as

$$H(z) = (1 + t_M) p_M a_{MQ}(z) + w_S a_{SQ}(z), \tag{2}$$

where p_M represents the world price of intermediate good M, and $a_{MQ}(z)$ and $a_{SQ}(z)$ are input coefficients of intermediate good M and skilled labor, respectively. To summarize the production technology in terms of the input coefficients, we have

$$\begin{aligned} a_{MQ} &= a_{MQ}(z), a_{MQ}(0) > 0, a_{MQ}^{'}(z) > 0, a_{MQ}^{''}(z) > 0, \\ a_{SQ} &= a_{SQ}(z), a_{SQ}(0) > 0, a_{SQ}^{'}(z) > 0, a_{SQ}^{''}(z) > 0, \end{aligned}$$

which implies that the unit-cost curve of product Q, $H(z)$, is convex in z. Unit-cost curve $H(z)$ is drawn in Figure 1. Notice that $H(z)$ will shift when the tariff rate t_M, or the world price of intermediate good M, p_M, or the wage of skilled labor, w_S, changes.

Suppose that the world-price curve of product Q, $W(z)$, is convex in z. That is, $W^{'}(z) > 0$ and $W^{''}(z) > 0$. For any given z, assume that $W(z) < H(z)$, which reflects the technology of product Q in the home country is in a lower level than foreign countries. We assume $W^{''}(z) < H^{''}(z)$ to imply

that the higher the quality is, the lower technology of product Q the home country has. In Figure 1, we can see that $H(z)$ is lower than $(1+t_Q)W(z)$ at the range of $[0, \bar{z})$ and larger than $(1+t_Q)W(z)$ at the range of $(\bar{z}, \infty)$. This means that the quality varieties at the range of $[0, \bar{z})$ can be produced in the home country but not be exported.

In fact, not all of the varieties at the range of $[0, \bar{z})$ are necessarily produced in the home country. Actually, the home country only produces the quality varieties chosen by domestic consumers at the range of $[0, \bar{z})$, which is discussed later. There are two groups of consumers in the home country: unskilled worker and skilled worker. They are identical except for income level. Their incomes are their wage plus the tariff revenues distributed to them, respectively. They can consume product A in every desirable quantity, whereas their consumption level of product Q is assumed to be fixed at unity. However, they can choose the quality of product Q from those available in the market.

A representative consumer with income I chooses a consumption level of product A and a quality level of product Q to solve the following problem:

$$\begin{aligned} & \max \ u(y,z) \\ s.t. \ y + p(z) \ & \leq \ I, \ y \geq 0, \ z \in Z. \end{aligned} \tag{3}$$

For simplicity, we assume the utility function is

$$u(y,z) = \min\left[y, \alpha z\right], \ \alpha > 0,$$

where y is the quantity of product A and z is the quality of product Q. $p(z)$ represents the price of quality z and Z is the set of qualities available in the home market.

The supply price of quality z is determined by

$$p(z) = \min[H(z), (1+t_Q)W(z)].$$

The supply price curve of quality goods is broken curve CDF in Figure 1. The break-even point D corresponds to a quality $\bar{z}$ that satisfies $H(\bar{z}) = (1+t_Q)W(\bar{z})$. The consumer problem (3) is represented graphically in Figure 2. The budget curve of consumer with an income level I is $y = I - p(z)$. The consumer chooses a combination of (y, z) on the budget curve at the point of consistency with the vertex of an indifference curve such as point B. An individual with a higher income faces a higher budget curve.

Denote income levels of unskilled worker and skilled worker by I_L and I_S, respectively. We can see in Figure 2 that there exists an income level– denoted by I_d– at which the consumer will choose quality $\bar{z}$. Assume that

the income level of skilled workers is higher than I_d and that of unskilled workers is lower than I_d, that is, $I_L < I_d < I_S$. Then skilled workers choose high quality $z_S(> \bar{z})$ that is imported from foreign countries and unskilled workers consume quality $z_L(< \bar{z})$ that is produced domestically. Hence, the home country actually only produces quality z_L, which is demanded by unskilled workers.

Quality z_L is solved by the consumer problem of unskilled workers. The supply price facing unskilled workers is $H(z) = (1+t_M)p_M a_{MQ}(z)+w_S a_{SQ}(z)$, and their budget curve is $y = I_L - [(1 + t_M)p_M a_{MQ}(z) + w_S a_{SQ}(z)]$. Then the solutions of consumer problem (3) for unskilled workers are as follows:

$$(1 + t_M)p_M a_{MQ}(z_L) + w_S a_{SQ}(z_L) + \alpha z_L = I_L, \tag{4}$$

$$y_L = \alpha z_L, \tag{5}$$

where y_L is the quantity of product A consumed by a representative unskilled worker. For convenience for later analysis, we rewrite (4) as

$$z_L = z_L(1, (1 + t_M)p_M, w_S, I_L). \tag{6}$$

Similarly, quality z_S is derived by the consumer problem of skilled workers. Skilled workers face the supply price $(1 + t_Q)W(z)$, and their budget curve is $y = I_S - (1 + t_Q)W(z)$. Then, the solutions of consumer problem (3) for skilled workers are as follows:

$$(1 + t_Q)W(z_S) + \alpha z_S = I_S, \tag{7}$$

$$y_S = \alpha z_S, \tag{8}$$

where y_S is the quantity of product A consumed by a representative skilled worker. (8) can be rewritten as

$$z_S = z_S(1, t_Q, I_S). \tag{9}$$

Since quality z_L is the only quality produced in the home country, then the actual production structure in the home country is similar to the specific-factor model. That is, unskilled labor is specific to the production of product A; intermediate good M is specific to the production of quality z_L and skilled labor is mobile between two sectors. But unlike the specific-factor model, the input of intermediate good M is unlimited.

Since quality z_L is consumed only by unskilled workers, then its output, x_L, is equal to the endowment of unskilled worker, L. That is,

$$x_L = L. \tag{10}$$

The profit maximization condition of quality z_L implies

$$p(z_L) = (1 + t_M)p_M a_{MQ}(z_L) + w_S a_{SQ}(z_L). \tag{11}$$

And the full-employment conditions for unskilled labor and skilled labor are as follows:

$$a_{LA}x_A = L, \tag{12}$$

$$a_{SA}x_A + a_{SQ}(z_L)x_L = S, \tag{13}$$

where S is the endowment of skilled labor and x_A is the output of product A. The demand for intermediate good M, x_M, is expressed as

$$x_M = a_{MQ}(z_L)x_L. \tag{14}$$

Equations of (1), (10), (11), (12), (13), and (14) construct the production side.

Since quality z_S is consumed by skilled workers, then we have

$$x_S = S, \tag{15}$$

where x_S represents the quantity of quality z_S required in the home country. Assume that the home country exports product A to balance the imports of the intermediate good M and quality z_S. Then the tariff revenue T is equal to

$$T = t_M p_M x_M + t_Q W(z_S)x_S. \tag{16}$$

Assume that ρ_S $(0 < \rho_S < 1)$ fraction of the tariff revenue is distributed to skilled workers. Then the income of skilled workers, I_S, is expressed by

$$I_S = w_S + \rho_S T/S. \tag{17}$$

and the income of unskilled workers, I_L, is represented by

$$I_L = w_L + (1 - \rho_S)T/L. \tag{18}$$

Equations of (6), (5), (8), (9), (16), (17) and (18) build the demand side. Hence, with the production and the demand sides, endogenous variables such as z_L, z_S, y_L, y_S, x_L, x_A, x_M, w_L, w_S, $p(z_L)$, T, I_L, I_S are determined. Then the unit-cost curve $H(z)$ in the equilibrium is also determined through (2).

3 The Skilled Labor Market

In this section, we will focus on the skilled labor market to determine the equilibrium wage of skilled labor by analyzing the supply and the demand curves of skilled labor in product Q sector. The supply curve S_{QS}, and the demand curve, S_{QD}, of skilled labor in product Q sector are shown in Figure 3, respectively. In Figure 3, the vertical axis measures the wage of skilled labor and the horizontal axis measures the total skilled labor endowment S, which is allocated between sector Q (measured from its origin O_Q) and sector A (measured from its origin O_A). The equilibrium wage of skilled labor is determined at the intersection point of curve S_{QS} and curve S_{QD}, point W.

3.1 Supply Curve of Skilled Labor in Sector Q

At the outset, we will show that supply curve S_{QS} of skilled labor in product Q sector is upward sloping relative to the origin O_Q. Next, based on this supply curve, we will discuss the relationship between the wage of skilled labor and the quality supplied by domestic firms.

The supply of skilled labor in product Q sector, S_{QS}, is defined as

$$S_{QS} \equiv S - S_{AD} = S - a_{SA}(w_L, w_S)x_A,$$

where $S_{AD} \equiv a_{SA}(w_L, w_S)x_A$ is the demand of skilled labor in sector A. Substitute (12) into this equation to obtain

$$S_{QS} = S - S_{AD} = S - L\frac{a_{SA}(w_L, w_S)}{a_{LA}(w_L, w_S)}. \tag{19}$$

This equation implies that at constant endowments and world prices, as the wage of skilled labor goes down, the supply of skilled labor in product Q sector, S_{QS}, decreases. At constant world prices, a reduction in the wage of skilled labor leads to an increase in the wage of unskilled labor, which is implied by (1). Then as the wage of skilled labor decreases, more of skilled labor and less of unskilled labor are required to produce one unit of A. That is, a_{SA} goes up and a_{LA} goes down. Hence, at constant endowments, as the wage of skilled labor decreases, the supply of skilled labor in product Q sector, S_{QS}, decreases (see Appendix A for a proof). This relationship can be expressed by

$$S_{QS} = S_{QS}(w_S),$$

and thus curve S_{QS} is upward sloping relative to the origin O_Q.

We will show that along curve S_{QS}, the quality supplied by domestic firms declines. In other words, as the wage of skilled labor decreases, the quality

supplied by domestic firms decreases. The quality supplied by domestic firms, z_L, is determined by

$$a_{SQ}(z_L) = \frac{S_{QS}}{x_L}. \tag{20}$$

As stated in section 2, the output of the quality supplied in the home country, x_L, does not change with the quality and is fixed at L–the endowment of unskilled workers. As stated above, $S_{QS} = S_{QS}(w_S)$, then we have

$$a_{SQ}(z_L) = \frac{S_{QS}(w_S)}{x_L}.$$

As mentioned in section 2, when quality z_L goes up, the demand for skilled labor to produce one unit of quality good z_L, $a_{SQ}(z_L)$, increases. Thus, as the wage of skilled labor decreases, the quality supplied by domestic firms declines due to a reduction in the supply of skilled labor, S_{QS} (see Appendix A for a proof). The relationship is expressed as

$$z_L^S = z_L^S(w_S), \tag{21}$$
$$\underset{+}{}$$

where z_L^S represents the quality supplied by domestic firms and small + refers to the positive relationship between w_S and the quality supplied by domestic firms, z_L. This relationship is shown by an upward sloping curve Z_S in Figure 4, in which the vertical axis measures the wage of the skilled worker.

3.2 Demand Curve of Skilled Labor in Sector Q

We will show that the demand curve of skilled labor in product Q sector, S_{QD}, is downward sloping relative to the origin O_Q. The demand for skilled labor in sector Q, S_{QD}, is determined by the quality chosen by unskilled workers, z_L, that is,

$$S_{QD} = a_{SQ}(z_L)L,$$

where L represents the endowment of unskilled workers. Since $a_{SQ}(z_L)$ increases as z_L rises, then this equation means that as the quality demanded by unskilled workers, z_L, goes up, the demand for skilled labor in sector Q, S_{QD}, rises. We will illustrate that as the wage of skilled labor, w_S, decreases, the quality required by unskilled workers, z_L, rises later. Hence, the demand for skilled labor in sector Q, S_{QD} increases as w_S decreases, that is, curve S_{QD} is upward sloping relative to the origin O_Q.

We will discuss that as the wage of skilled labor, w_S, decreases, the quality required by unskilled workers, z_L, rises. From demand side, we obtain the following equations:

$$z_L = z_L(1, (1+t_M)p_M, w_L, w_S, T), \tag{22}$$

$$T = T(t_M, z_L, t_Q, z_S), \tag{23}$$

$$z_S = z_S(1, t_Q, w_S, T). \tag{24}$$

These equations are shown in implicit way by (B1), (B2) and (B3), in Appendix B respectively. The first equation is derived by substituting (18) into (6). The second one is derived by substituting (10), (14) and (15) into (16). And the third one is obtained by substituting (17) into (9). Based on these equations and (1), we have

$$z_L = z_L(w_S, t_M, t_Q), \tag{25}$$

$$T = T(w_S, t_M, t_Q), \tag{26}$$

$$z_S = z_S(w_S, t_M, t_Q),$$

The first equation shows that at constant tariff rates, the quality required by unskilled workers z_L, depends on the wage of skilled labor, w_S. This relationship is expressed by (see Appendix B for a proof)

$$A_2 dz_L = -\frac{S}{L} A_1 dw_S, \tag{27}$$

where $1 > A_1 > 0$ and $A_2 > 0$. This equation means that as the wage of skilled labor, w_S, decreases, the quality demanded by unskilled workers, z_L, increases. Then (25) can be rewritten as

$$z_L^D = z_L^D(\underset{-}{w_S}, t_M, t_Q), \tag{28}$$

where z_L^D represents the quality demanded by unskilled workers and small $-$ refers to the reverse relationship between w_S and the quality required by unskilled workers at constant tariff rates. This relationship is shown by an downward sloping curve Z_D in Figure 4.

In Figure 4, the intersection point Q_E of curve Z_D and curve Z_S determines the equilibrium wage of skilled labor and the equilibrium quality produced in the home country at the same time.

4 Trade Liberalization

In this section, we will investigate implications of trade liberalization. To do this, we will investigate how curve Z_D and curve Z_S shift when each of tariff rates decreases. As (21) shown, curve Z_S relies only on the wage of skilled labor, then reductions in the tariff rates will have no impacts on curve Z_S. Hence, the target is to investigate how curve Z_D moves when each of tariff rates decreases.

4.1 Trade Liberalization in Intermediate Good

At constant world prices and constant tariff rate on final quality goods, t_Q, we will show that a reduction in the tariff rate on intermediate good M, t_M brings about an increase in both the wage of skilled labor and the quality produced in the home country.

At the outset, we will illustrate that a reduction in t_M leads to curve Z_D shifting to the right to $Z_D^{t_M}$ in Figure 4. At constant world prices, substitute (26) and the relationship between w_L and w_S into (22), we have

$$z_L^D = z_L^D(w_S, t_M, T(w_S, t_M, t_Q)), \tag{29}$$

which is same as (28). At constant wages, world prices and the tariff rate on quality goods, t_Q, totally differentiate this equation to obtain

$$dz_L = \frac{\partial z_L}{\partial t_M} dt_M + \frac{\partial z_L}{\partial T}\frac{\partial T}{\partial t_M} dt_M. \tag{30}$$

This equation shows that a reduction in t_M has a direct effect and an indirect effect on the quality required by unskilled workers, z_L. The direct effect, $\frac{\partial z_L}{\partial t_M}$, is due to a shift of the budget curve of unskilled workers, and we call it the supply price effect. At constant world prices and wages, as t_M goes down, the unit-cost curve of domestic quality goods, $H(z)$, shifts downward. At constant wage and tariff revenue, the income of unskilled workers is constant, then the budget curve of unskilled workers shifts upward. It follows that the quality required by unskilled workers goes up, that is, $\frac{\partial z_L}{\partial t_M} < 0$, which is shown by (B9) in Appendix B.

The indirect effect, $\frac{\partial z_L}{\partial T}\frac{\partial T}{\partial t_M}$, is due to a change in the tariff revenue, and we call it the tariff revenue effect. At constant wages, as tariff revenue decreases, the income level of unskilled workers decreases. It follows that the quality chosen by unskilled workers, z_L, goes down. That is, $\frac{\partial z_L}{\partial T} > 0$, which is shown by (B10) in Appendix B. At constant wages and constant t_Q, the tariff revenue will decrease due to a reduction in t_M. That is, $\frac{\partial T}{\partial t_M} > 0$, which is shown by (B12) in Appendix B. Thus, the tariff revenue effect is positive. We show that the net effect of the supply price effect and the tariff revenue effect is negative, that is, $\frac{\partial z_L}{\partial t_M} + \frac{\partial z_L}{\partial T}\frac{\partial T}{\partial t_M} < 0$, by (B13) in Appendix B. This means that at constant wages, a reduction in t_M leads to an increase in the quality chosen by unskilled workers, z_L. In other words, curve Z_D will shift to the right to curve $Z_D^{t_M}$.

In Figure 4, we can see that a reduction in t_M leads to an increase in both the wage of skilled workers the quality produced in the home country. The increase in the quality produced domestically implies that the utility of unskilled workers increases. The increase in the wage of skilled labor implies

that the wage of unskilled workers goes down. That is, the wage inequality enlarges. In other words, a reduction in the tariff rate of the intermediate good will favor skilled labor but harm unskilled labor in terms of wage.

But a reduction in the tariff rate of the intermediate good results in a decrease in the quality chosen by skilled workers (shown by (C4) in Appendix C), which implies a reduction in their utility. This is because a reduction in the tariff rate of the intermediate good brings about a decrease in their income (shown by (C5) in Appendix C).

4.2 Trade Liberalization in Final Quality Goods

We will turn to the implication of trade liberalization in final goods. At constant world prices and constant tariff rate of intermediate good, t_M, we will show that a reduction in the tariff rate of quality goods, t_Q, leads to a decrease in both the wage of skilled labor and the quality produced in the home country.

At the outset, we will examine that a reduction in t_Q brings about curve Z_D shifting to the left to $Z_D^{t_Q}$ in Figure 4. At constant wages and constant t_M, totally differentiate (29) to obtain

$$dz_L = \frac{\partial z_L}{\partial T}\frac{\partial T}{\partial t_Q}dt_M.$$

This equation means that a reduction in t_Q has no supply price effect but the tariff revenue effect, $\frac{\partial z_L}{\partial T}\frac{\partial T}{\partial t_Q}$, on the quality required by unskilled workers, z_L. In fact, a reduction in t_Q has a supply price effect on the quality required by skilled workers, z_S.[1] At constant wages and constant tariff rate t_M, a reduction in t_Q will lead to a decrease in tariff revenue. That is, $\frac{\partial T}{\partial t_Q} > 0$, which is shown by (B14) in Appendix B. Since $\frac{\partial z_L}{\partial T} > 0$, then $\frac{\partial z_L}{\partial T}\frac{\partial T}{\partial t_Q} > 0$, which is shown by (B15) in Appendix B. This means that at constant wages and constant tariff rate t_M, a reduction in t_Q leads to an decrease in the quality chosen by unskilled workers, z_L. In other words, curve Z_D will shift to the left to curve $Z_D^{t_Q}$.

In Figure 4, we can see that a reduction in t_Q leads to a decline in both the wage of skilled labor and the quality produced in the home country. The reduction in the quality produced domestically implies that the utility of unskilled workers decreases. The reduction in the wage of skilled labor implies that the wage of unskilled workers goes up. That is, the wage inequality

[1] At constant income level, as t_Q is reduced, the world price curve shifts down and then the budget curve of skilleld workers shift upward. Then the quality required by them increase.

contracts. Put it in another way, a reduction in the tariff rate of final quality goods benefits unskilled labor in terms of wage.

The quality chosen by skilled workers increases (shown by (C4) in Appendix C), because a reduction in the tariff rate of final quality goods brings about an increase in their income level (shown by (C5) in Appendix C). Thus, the utility of skilled workers increases. But they are deteriorated in terms of wage by a reduction in the tariff rate on final quality goods.

5 Conclusion

This paper develops a quality goods model to analyze the effects of trade liberalization in China on its wage inequality. We find that trade liberalizations in the intermediate goods and in final quality goods have totally different effects on wage inequality and the quality produced domestically.

Trade liberalization in intermediate goods increases the wage inequality and the quality produced domestically, while trade liberalization in final quality goods reduces the wage inequality and the quality produced domestically. In other words, trade liberalization in intermediate goods benefits skilled labor, while trade liberalization in final quality goods benefits unskilled labor in terms of wage.

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Appendix A

Totally differentiate (19) to obtain

$$\hat{S}_{QS} = \hat{S} - \frac{L}{S}\frac{a_{SA}}{a_{LA}}(\hat{a}_{SA} - \hat{a}_{LA}).$$

The elasticity of substitution in sector A, σ_A, is defined as

$$\sigma_A = \frac{\hat{a}_{SA} - \hat{a}_{LA}}{\hat{w}_L - \hat{w}_S}.$$

With the above two equations, we have

$$\hat{S}_{QS} = -\lambda_{SA}\sigma_A(\hat{w}_L - \hat{w}_S), \tag{A1}$$

where $\hat{S} = 0$ at constant endowment of skilled labor and $\lambda_{SA} \equiv \frac{L}{S}\frac{a_{SA}}{a_{LA}}$ represents the fraction of skilled labor used in sector A.

Totally differentiate (1) to derive

$$\theta_{LA}\hat{w}_L + \theta_{SA}\hat{w}_S = 0, \tag{A2}$$

where $\theta_{iA} \equiv w_i a_{iA}/p_A$ $(i = L, S)$ refers to the share of factor i in sector A. Substitute this equation to (A1) to get

$$\hat{S}_{QS} = \frac{\lambda_{SA}\sigma_A}{\theta_{LA}}\hat{w}_S, \tag{A3}$$

which means that as the wage of skilled worker decreases, the supply of skilled labor in the quality good sector decreases.

Totally differentiae (20) to obtain

$$\hat{S}_{QS} = \frac{a'_{SQ}(z_L)}{a_{SQ}(z)}dz.$$

Substitute this equation into (A3) to derive

$$dz_L = \frac{\lambda_{SA}\sigma_A}{\theta_{LA}}\frac{a_{SQ}(z_L)}{a'_{SQ}(z_L)}\hat{w}_S, \tag{A4}$$

which means that as the wage of the skilled labor goes down, the supplied quality goes down.

Appendix B

1. The relationship between the wage of skilled labor and the quality demanded by unskilled workers

Substitute (18) into (4) to obtain

$$\alpha z_L + w_S a_{SQ}(z_L) + (1+t_M)p_M a_{MQ}(z_L) = w_L + (1-\rho_S)T/L. \tag{B1}$$

Substitute (17) into (7) to derive

$$\alpha z_S + (1+t_Q)W(z_S) = w_S + \rho_S T/S. \tag{B2}$$

Substitute (10), (14) and (15) into (16) to obtain

$$T = t_M p_M a_{MQ}(z_L)L + t_Q W(z_S)S. \tag{B3}$$

At constant world price of intermediate good M, p_M, totally differentiate (B1), (B2) and (B3) to obtain

$$dz_L = \frac{1}{A_0}[dw_L - a_{SQ}(z_L)dw_S - p_M a_{MQ}(z_L)dt_M + (1-\rho_S)/LdT], \tag{B4}$$

where

$$A_0 \equiv \alpha + w_S a'_{SQ}(z_L) + (1+t_M)p_M a'_{MQ}(z_L) > 0$$

$$dz_S = \frac{1}{\alpha + (1+t_Q)W'(z_S)}[dw_S - W(z_S)dt_Q + \frac{\rho_S}{S}dT], \tag{B5}$$

$$dT = p_M a_{MQ}(z_L)Ldt_M + t_M p_M a'_{MQ}(z_L)Ldz_L + W(z_S)Sdt_Q + t_Q W'(z_S)Sdz_S. \tag{B6}$$

Substitute (B5) into (B6) to derive

$$\begin{aligned} dT &= \frac{1-A_1}{1-\rho_S}Sdw_S + \frac{1-\rho_S A_1}{1-\rho_S}p_M a_{MQ}(z_L)Ldt_M \\ &\quad + A_1 SW(z_S)dt_Q + \frac{1-\rho_S A_1}{1-\rho_S}t_M p_M a'_{MQ}(z_L)Ldz_L, \end{aligned} \tag{B7}$$

where

$$A_1 \equiv \frac{\alpha + W'(z_S)}{\alpha + [(1+(1-\rho_S)t_Q]W'(z_S)} > 0.$$

$$\frac{1-\rho_S A_1}{1-\rho_S} \equiv \frac{\alpha + (1+t_Q)W'(z_S)}{\alpha + [(1+(1-\rho_S)t_Q]W'(z_S)} > 1$$

Substitute this equation into (B4) to derive

$$\begin{aligned} A_2 dz_L &= dw_L - a_{SQ}(z_L)dw_S + \frac{S}{L}(1-A_1)dw_S \\ &\quad -\rho_S p_M a_{MQ}(z_L)A_1 dt_M + (1-\rho_S)\frac{S}{L}W(z_S)A_1 dt_Q, \end{aligned}$$

where

$$A_2 \equiv \alpha + w_S a_{SQ}^{'}(z_L) + p_M a_{MQ}^{'}(z_L) + \rho_S t_M p_M a_{MQ}^{'}(z_L)A_1 > 0.$$

Rewrite (A2) to obtain

$$dw_L = -\frac{a_{SA}}{a_{LA}}dw_S.$$

Substitute this equation into the above equation to obtain

$$A_2 dz_L = -\frac{S}{L}A_1 dw_S - \rho_S p_M a_{MQ}(z_L)A_1 dt_M + (1-\rho_S)\frac{S}{L}W(z_S)A_1 dt_Q, \quad \text{(B8)}$$

where this equation hold because with (13), we have

$$\begin{aligned} &\frac{S}{L}(1-A_1) - \frac{a_{SA}}{a_{LA}} - a_{SQ}(z_L) \\ =\ &\frac{S}{L} - (\frac{a_{SA}x_A}{a_{LA}x_A} + \frac{a_{SQ}(z_L)L}{L}) - \frac{S}{L}A_1 \\ =\ &-\frac{S}{L}A_1. \end{aligned}$$

At constant wage and constant t_Q, (B8) shows that the effect of a reduction in t_M on the quality demanded by unskilled workers, z_L is $-\rho_S p_M a_{MQ}(z_L)A_1 < 0$. And at constant wage and constant t_M, this equation illustrates that the effect of a reduction in t_Q on the quality demanded by unskilled workers, z_L is $(1-\rho_S)\frac{S}{L}W(z_S)A_1 > 0$.

Under constant tariff rates, (B8) is equal to

$$A_2 dz_L = -\frac{S}{L}A_1 dw_S,$$

which is (27).

2. The net effect of a reduction in the tariff rate on intermediate good on the quality demanded by unskilled workers

From (B4), we have

$$\frac{\partial z_L}{\partial t_M} = -\frac{p_M a_{MQ}(z_L)}{A_0} < 0, \quad \text{(B9)}$$

and

$$\frac{\partial z_L}{\partial T} = \frac{(1-\rho_S)}{LA_0} > 0. \tag{B10}$$

Substitute (B8) into (B7) to derive

$$\begin{aligned} dT &= \frac{S}{1-\rho_S}[1-\frac{A_1A_0}{A_2}]dw_S + \frac{A_0A_1SW(z_S)}{A_2}dt_Q \\ &\quad + p_M a_{MQ}(z_L)L\frac{A_3}{A_2}\frac{1-\rho_S A_1}{1-\rho_S}dt_M. \end{aligned} \tag{B11}$$

where

$$A_3 \equiv \alpha + w_S a'_{SQ}(z_L) + p_M a'_{MQ}(z_L) > 0$$

From this equation, we obtain

$$\frac{\partial T}{\partial t_M} = p_M a_{MQ}(z_L)L\frac{A_3}{A_2}\frac{1-\rho_S A_1}{1-\rho_S} > 0. \tag{B12}$$

Then

$$\begin{aligned} \frac{\partial z_L}{\partial t_M} + \frac{\partial z_L}{\partial T}\frac{\partial T}{\partial t_M} &= \frac{p_M a_{MQ}(z_L)}{A_0}[\frac{(1-\rho_S A_1)A_3}{A_2} - 1] \\ &= -\frac{\rho_S p_M a_{MQ}(z_L)A_1}{A_2} < 0, \end{aligned} \tag{B13}$$

which is same as the net effect of a reduction in t_M on the quality demanded by unskilled workers, z_L, in (B10).The proof for the tariff revenue effect of a reduction in the tariff rate on quality goods on the quality demanded by unskilled workers.

From (B11), we have

$$\frac{\partial T}{\partial t_Q} = W(z_S)SA_0A_1 > 0. \tag{B14}$$

Then together with (B10), we have

$$\begin{aligned} \frac{\partial z_L}{\partial T}\frac{\partial T}{\partial t_Q} &= \frac{(1-\rho_S)}{LA_0}W(z_S)SA_0A_1 \\ &= (1-\rho_S)\frac{S}{L}W(z_S)A_1, \end{aligned} \tag{B15}$$

which is same as the effect of a reduction in t_Q on the quality demanded by unskilled workers, z_L, in (B10).

Appendix C

3. The effects of reductions in the tariff rates on the quality required by unskilled workers and the wage of skilled labor in the equilibrium

Together with (A4) and (B8), we have

$$A_4 dz_L = -\rho_S p_M a_{MQ}(z_L) A_1 dt_M + (1-\rho_S)\frac{S}{L} W(z_S) A_1 dt_Q, \qquad \text{(C1)}$$

where

$$A_4 \equiv A_2 + \frac{S}{L} A_1 \frac{w_S a'_{SQ}(z_L)}{a_{SQ}(z_L)} \frac{\theta_{LA}}{\lambda_{SA}\sigma_A} > 0.$$

This equations shows that a reduction in the tariff rate of intermediate good leads to a reduction in the quality produced in the home country, z_L, whereas a reduction in the tariff rate on final quality goods brings about an increase in z_L.

Substitute (C1) into (B8) to derive

$$dw_S = -\frac{L}{S}(1-\frac{A_2}{A_4})\rho_S p_M a_{MQ}(z_L) dt_M + (1-\frac{A_2}{A_4})(1-\rho_S) W(z_S) dt_Q, \quad \text{(C2)}$$

where $1-\frac{A_2}{A_4} > 0$. This equations shows that a reduction in the tariff rate on intermediate good leads to a reduction in the the wage of skilled labor, w_s, whereas a reduction in the tariff rate on final quality goods brings about an increase in w_s.

4. The effects of reductions in the tariff rates on the tariff revenue and the quality required by skilled workers

Substitute (C2) into (B11) to obtain

$$\begin{aligned} dT &= p_M a_{MQ}(z_L) L\{1 - \frac{A_2}{A_4} + \frac{1-\rho_S A_1}{1-\rho_S}\frac{A_3}{A_4}\} dt_M \\ &\quad + W(z_S) S\{1 - \frac{A_2}{A_4} + \frac{A_1 A_0}{A_4}\} dt_Q, \end{aligned} \qquad \text{(C3)}$$

Since $A_4 > A_2 > 0$, this equation means that reductions in both tariff rates lead to reductions in the tariff revenue.

Substitute (C2) and (C3) into (B5) to obtain

$$dz_S = A_5[\rho_S p_M a_{MQ}(z_L)\frac{L}{S} dt_M - (1-\rho_S) W(z_S) dt_Q], \qquad \text{(C4)}$$

where

$$A_5 \equiv \frac{A_3}{A_4}\frac{1}{[1+(1-\rho_S)t_Q]W'(z_S)+\alpha} > 0.$$

This equation shows that a reduction in the tariff rate of intermediate good leads to a reduction in the quality required by skilled labor, z_S, whereas a reduction in the tariff rate on final quality goods brings about an increase in z_S.

5. The effects of reductions in the tariff rates on the income levels

Totally differentiate (17) to derive

$$dI_S = dw_S + \frac{\rho_S}{S}dT.$$

Substitute (C2) and (C3) into this equation to obtain

$$\begin{aligned} dI_S &= \frac{1-\rho_S A_1}{1-\rho_S}\frac{A_3}{A_4}\rho_S p_M a_{MQ}(z_L)\frac{L}{S}dt_M \\ &\quad +W(z_S)[1-\frac{(1-\rho_S A_1)A_3}{A_4}]dt_Q, \end{aligned} \tag{C5}$$

Since $1 > 1-\rho_S A_1 > 0$ and $A_4 > A_3 > 0$, then $1 > \frac{(1-\rho_S A_1)A_3}{A_4} > 0$. This equation means that reductions in both tariff rates leads to reductions in income level of skilled workers.

Totally differentiate (18) to obtain

$$dI_L = dw_L + \frac{(1-\rho_S)}{L}dT.$$

Substitute (A2), (C2) and (C3) into this equation to derive

$$\begin{aligned} dI_L &= p_M a_{MQ}(z_L)\{1-\frac{\rho_S A_0 A_1}{A_4}-\rho_S\frac{La_{SQ}(z_L)(1-\frac{A_2}{A_4})}{S}\}dt_M \\ &\quad +(1-\rho_S)W(z_S)\{(1-\frac{A_2}{A_4})a_{SQ}(z_L)+\frac{S}{L}\frac{A_1 A_0}{A_4}\}dt_Q, \end{aligned} \tag{C6}$$

where

$$\begin{aligned} & 1-\frac{\rho_s A_0 A_1}{A_4}-\rho_S\frac{La_{SQ}(z_L)(1-\frac{A_2}{A_4})}{S} \\ = \; & 1-\frac{\rho_S A_1}{A_4}[A_0+w_S a'_{SQ}(z_L)\frac{\theta_{LA}}{\lambda_{SA}\sigma_A}] > 0. \end{aligned}$$

The second inequality holds because $1 > A_1 > 0$ and $\frac{S}{La_{SQ}(z_L)} > 1$ then $\rho_S A_1[A_0 + w_S a'_{SQ}(z_L)\frac{\theta_{LA}}{\lambda_{SA}\sigma_A}] < A_4$. Eq. (C3) shows that reductions in both tariff rates brings about reductions in the income level of unskilled workers.

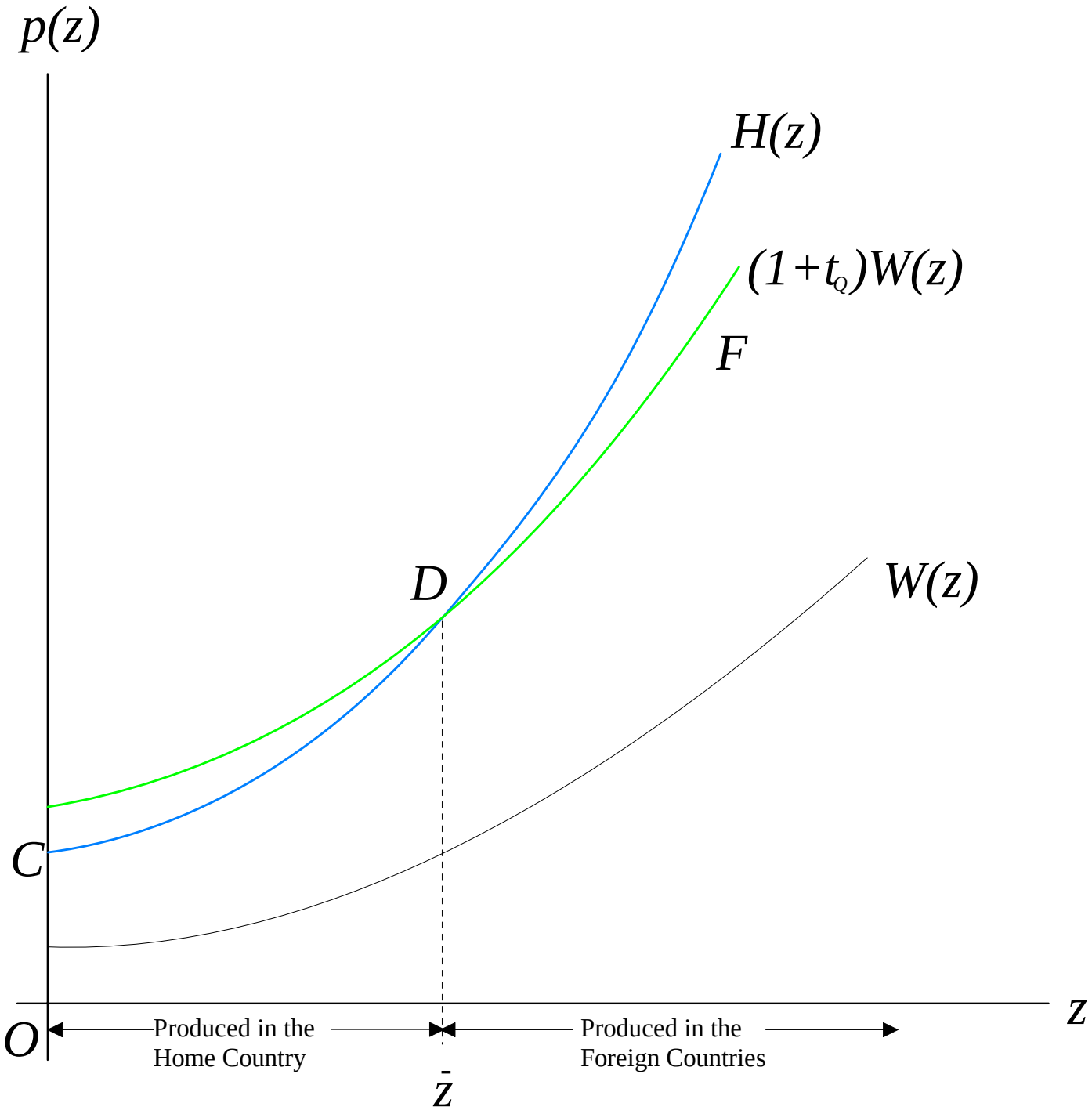

Figure 1 The supply price of product Q

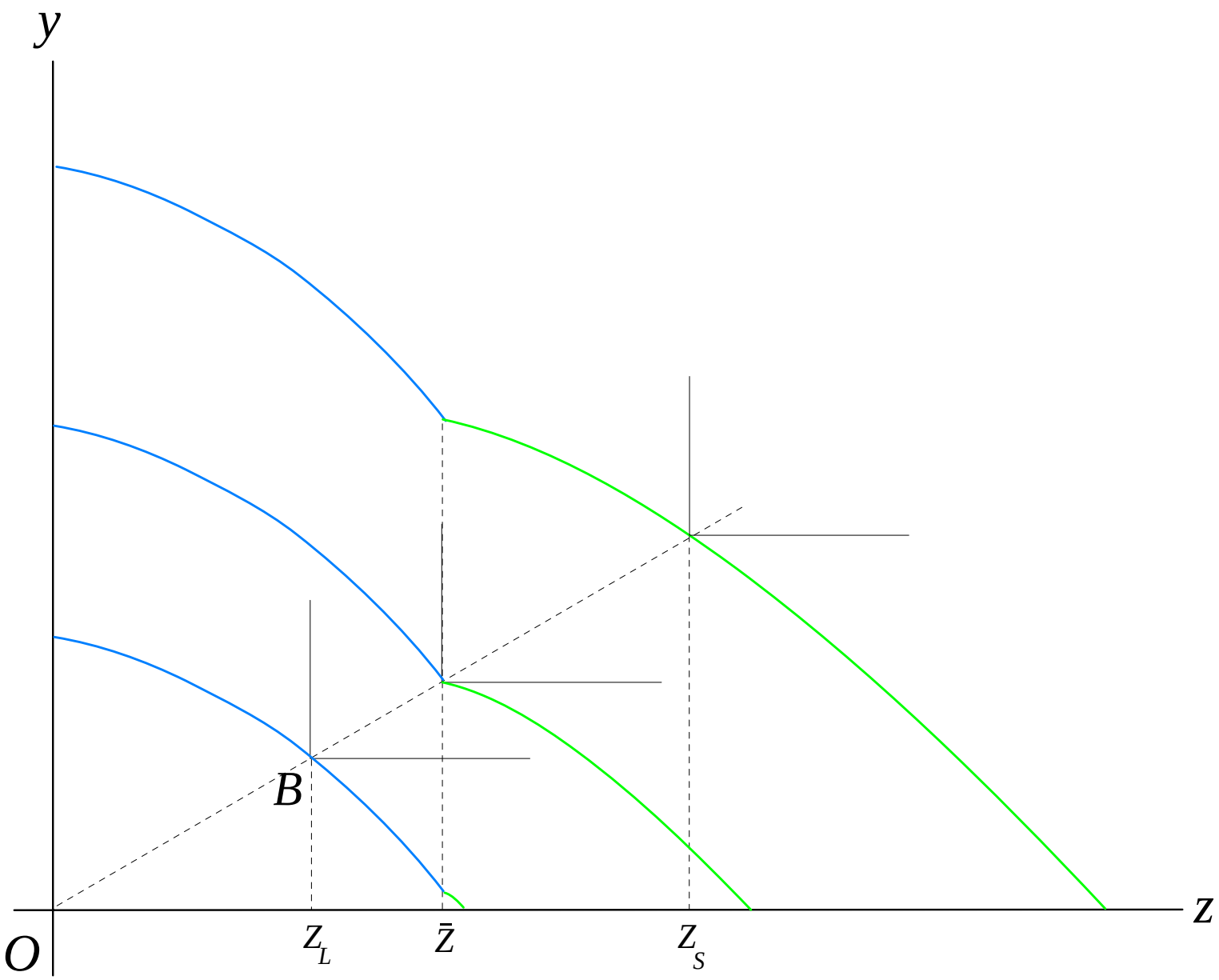

Figure 2　The Budget Curves

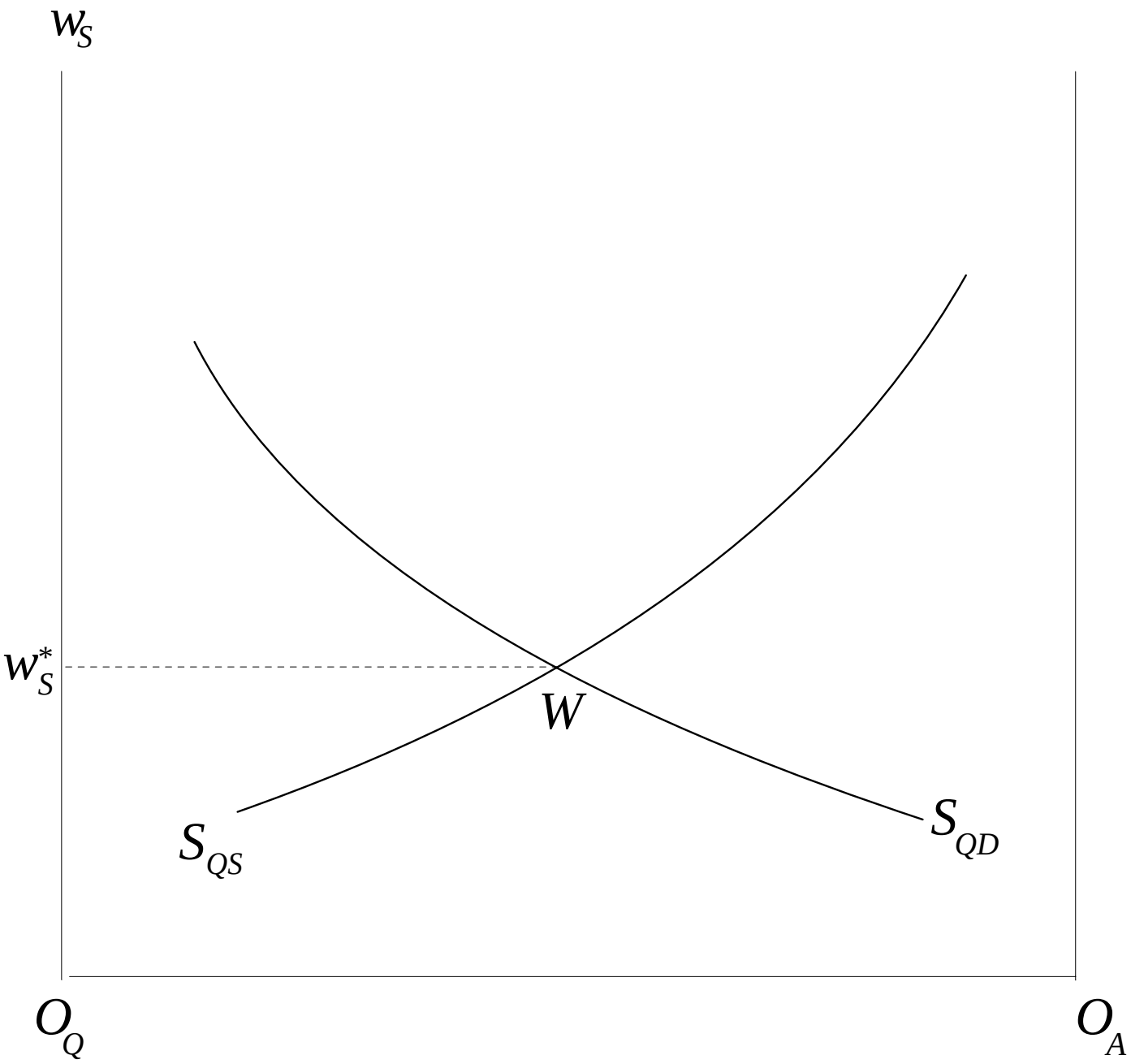

Figure 3　The Skilled Labor Market

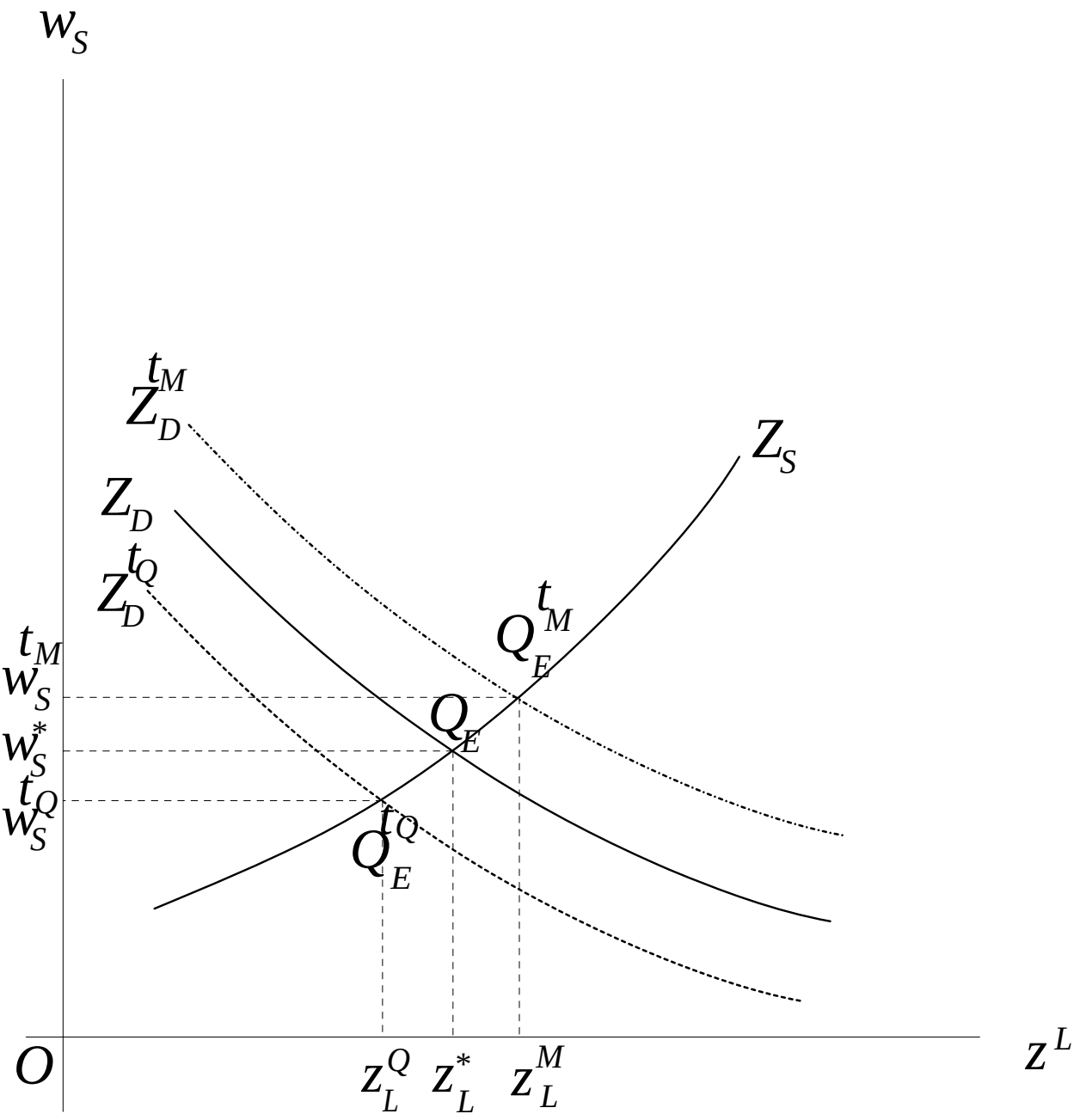

Figure 4 The Equilibrium Wage and Quality