Discussion Papers In Economics And Business

Nonlinear Effects of the Transport Costs on the Wage Inequality

Yuichiro Matsumoto

Discussion Paper 18-07

Graduate School of Economics and
Osaka School of International Public Policy (OSIPP)
Osaka University, Toyonaka, Osaka 560-0043, JAPAN

Nonlinear Effects of the Transport Costs on the Wage Inequality

Yuichiro Matsumoto

Discussion Paper 18-07

March 2018

Graduate School of Economics and
Osaka School of International Public Policy (OSIPP)
Osaka University, Toyonaka, Osaka 560-0043, JAPAN

Nonlinear Effects of the Transport Costs on the Wage Inequality*

Yuichiro Matsumoto†

March 6, 2018

Abstract

This paper examines how transport costs affect wage inequality. Goods produced by the unskilled must pay higher transport costs because they have low market values. Reduction in transportation cost changes the relative wage. At first, only the skilled gains from the transportation improvement. Then the unskilled also gains from international trade. Therefore, transportation development causes Kuznets curve.

JEL Classification Codes: F16; J31; L91; O11; R1

Keywords: Alchian-Allen Hypothesis; Kuznets Curve; Trade Liberalization; Transportation Infrastructure; Wage Inequality

---

*I am grateful to the seminar participants at Osaka University.

†Osaka University email:u847103e@ecs.osaka-u.ac.jp

1 Introduction

Transportation has a sizable impact on the economy. Railroads in colonial India increased the agricultural income more than 17 percent (Donaldson (2010)). Donaldson and Hornbeck (2016) suggested that if all the US railroads in 1890 had been removed, the agricultural land value would have decreased by 60 percent. The regions with the top 25th percentile transportation infrastructures have 68 percent larger trade volume than the median regions (Limao and Venables (2001)). It is true that the economists realize the importance of the transportation.

However, less attention has been paid to the fact that gains from the transportation are different across workers. The costs for transportation are more costly for more cheap goods because the physical properties such as the mass determine the transportation costs (Alchian and Allen (1972); Hummels and Skiba (2004); Irarrazabal et al. (2015); Lugovskyy and Skiba (2015)). This fact is important for income distribution because cheap goods are often produced by the unskilled (Verhoogen (2008)). Then, higher trade burden reduces the unskilled wage.[1]

The purpose of this study is to show that this natural presumption leads to a somewhat unexpected result. To see this, we cite the following fact: if the transport costs are extremely high or low, the cost difference does not matter for inequality because transport costs are not used in these cases. This result suggests

[1]Admittedly, many previous studies examined the implication of sector specific trade costs for the goods demand and the industrial structure. Feenstra (1988) examined the idea that import quotas increase the import of the high quality goods. Hanson and Xiang (2004) showed that agglomeration force is strong for the sector with high transport costs. However, as I know, the effect for factor demands is not examined before.

the nonlinear effect of transport costs for wage inequality.

Main results are summarized as follows. First, transportation development causes Kuznets curve (Kuznets (1955)). Interestingly, similar, although distinct, nonlinear behavior was observed in Banerjee et al. (2012): the access of transportation infrastructures improves the middle-class income at the expense of the income of the other classes. It also indicates that the sufficient investment for transportation may reduce inequality.

Second, the effect of the trade liberalization depends on the relative import shares (Arkolakis et al. (2012)). It also implies that the size of the effect is nonlinear—the effect magnifies: with low openness, the effect of trade for inequality is low; as openness increases, however, the effect of the trade becomes sizable.

To make the point clear, section 2 uses the iceberg specification of the transport costs. However, this specification does not incorporate the idea that cheap goods values cause the high transport costs. Then, section 3 modifies the specification of transport costs. In this case, the absolute level of the skill premium matters because it determines the market value of the goods. Section 4 concludes.

2 Model

Consider the economy with $M+1$ countries. For tractability, we assume symmetric countries, which is a reasonable assumption because the factor difference is not so important. Indeed, international trades mainly occurs between similar countries (Krugman (2000); Waugh (2010)). [2]

The final goods Y_i in country i is produced by the technology:

$$Y_i = (\beta_s^{\frac{1}{\epsilon}} Y_{si}^{\frac{\epsilon-1}{\epsilon}} + \beta_u^{\frac{1}{\epsilon}} Y_{ui}^{\frac{\epsilon-1}{\epsilon}})^{\frac{\epsilon}{\epsilon-1}} \tag{1}$$

where Y_{si} and Y_{ui} denote the composite skill and unskilled intensive goods respectively. $\epsilon > 1$ denotes the elasticity of substitution across goods with different skill intensity. Composite goods Y_{hi} are produced by internationally differentiated goods (Armington (1969)):

$$Y_{hi} \equiv (\sum_{j=0}^{M} y_{hij}^{\frac{\rho-1}{\rho}})^{\frac{\rho}{\rho-1}} \tag{2}$$

where y_{hij} is the quantity of the intermediate goods sold from country j to i.

All markets are competitive, which implies

$$\begin{aligned} \frac{P_{si}Y_{si}}{P_{ui}Y_{ui}} &= \frac{\beta_s}{\beta_u}(\frac{P_{si}}{P_{ui}})^{1-\epsilon} \\ \frac{p_{hii}y_{hii}}{p_{hij}y_{hij}} &= (\frac{p_{hii}}{p_{hij}})^{1-\rho} \end{aligned} \tag{3}$$

where p_{hij} is the price of y_{hij}. P_{hi} is the price indexes

$$P_{hi} \equiv (\sum_j p_{hij}^{1-\rho})^{\frac{1}{1-\rho}} \tag{4}$$

[2]Moreover, even unskilled abundant developing countries—in contrast to the prediction of factor proportion theory—increased wage inequality after liberalization (Goldberg and Pavcnik (2007); Verhoogen (2008)).

Then, we consider the intermediate goods. Following Epifani and Gancia (2008), we assume that intermediate goods are produced only by sector-specific labors. For each sector, unit labor requirement is one. In addition, exporters must pay $\theta_h \tau_p$ units of iceberg transport cost and τ_t units of the wasted tariff. The transport cost is low for high quality goods: $\theta_s < \theta_u$. Then prices are

$$p_{hii} = w_h, \quad p_{hij} = (1 + \theta_h \tau_p)(1 + \tau_t) w_h \quad i \neq j \tag{5}$$

where w_h denotes the wage of the sector h. By symmetry, we omit the subscript i.

Now we see the distribution of revenues. They are distributed to the inputs:

$$P_{hi} Y_h = w_h L_h \tag{6}$$

where L_h is the labor force h within a country.

Consequently, we can obtain the equilibrium skill premium $\omega \equiv \frac{w_s}{w_u}$. From (3), (4), (5) and (6),

$$\omega^{\epsilon} = (\frac{L_u}{L_s})(\frac{1 + \hat{M}(1 + \theta_s \tau_p)^{1-\rho}}{1 + \hat{M}(1 + \theta_u \tau_p)^{1-\rho}})^{\frac{1-\epsilon}{1-\rho}} \tag{7}$$

where $\hat{M} \equiv M(1 + \tau_t)^{1-\rho}$ is a measure of openness, which is large when tariff τ_t is low or there are many trade partners M.

Before proceeding, it is instructive to note that the transport cost is extremely high or low, the skill premium is unaffected by it: $\lim_{\tau_p \to 0} \omega = \lim_{\tau_p \to \infty} \omega =$

$(\frac{L_u}{L_s})^{1/\epsilon}$. This result is obtained because transport costs are not used in these cases. This result indicates that some nonlinearity exists.

2.1 Trade Liberalization

The effect of trade liberalization is

$$\frac{d\log\omega}{d\log\hat{M}} = \frac{\epsilon-1}{\epsilon(\rho-1)}(\frac{\hat{M}(1+\theta_s\tau_p)^{1-\rho}}{1+\hat{M}(1+\theta_s\tau_p)^{1-\rho}} - \frac{\hat{M}(1+\theta_u\tau_p)^{1-\rho}}{1+\hat{M}(1+\theta_u\tau_p)^{1-\rho}}) > 0 \quad (8)$$

where $\frac{\hat{M}(1+\theta_h\tau_p)^{1-\rho}}{1+\hat{M}(1+\theta_h\tau_p)^{1-\rho}} = \frac{\sum_{j\neq i} p_{hij}y_{hij}}{\sum_j p_{hij}y_{hij}}$ is the sectoral import share. The import share is higher for the skill intensive sector, which is roughly consistent with the empirical facts (Bernard and Jensen (1995); Bernard et al. (2012)). Then, trade costs increases inequality (See also Figure 1). The trade liberalization is more beneficial for the labor who works in the sector where more goods is exported.

The size of the effect is also suggestive. High trade costs implies the negligible impact of liberalization: $\lim_{\hat{M}\to 0}\frac{d\ln\omega}{d\ln\hat{M}} = \lim_{\tau_P\to\infty}\frac{d\ln\omega}{d\ln\hat{M}} = 0$. With negligible trade volume, the effect of trade for wage inequality is also negligible. Moreover, as the trade volume expands by trade liberalization, the effect of the interregional trade is increasing. Indeed, we can show that the size of the effect of trade liberalization expands if the import share of skill intensive goods is lower than 0.5 (see appendix). Hence, policymakers must carefully handle with information from the previous liberalization to evaluate the effect of the additional liberalization.

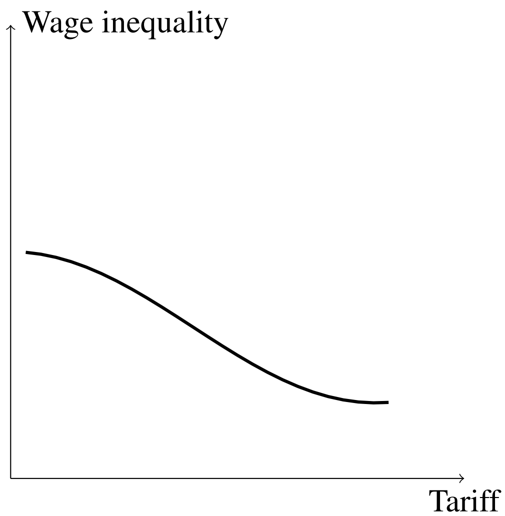

Figure 1: Trade liberalization and wage inequality.

2.2 Transportation Costs and Kuznets Curve

The effect of the transportation technology is much more complicated:

$$\begin{aligned}\frac{\partial \log \omega}{\partial \tau_p} = \frac{\epsilon - 1}{\epsilon} \prod_h \frac{\hat{M}(1+\theta_h \tau_p)^{-\rho}}{1 + \hat{M}(1+\theta_h \tau_p)^{1-\rho}} \\ \cdot (\theta_u (1+\theta_s \tau_p)^{\rho} - \theta_s (1+\theta_u \tau_p)^{\rho} - \hat{M}(\theta_s - \theta_u))\end{aligned} \tag{9}$$

However, it can be shown that $\omega(\tau_p)$ has inverted U shape, which is reminiscent of Kuznets curve (See Figure 2). This is because $\theta_u(1+\theta_s\tau_p)^{\rho} - \theta_s(1+\theta_u\tau_p)^{\rho} - \hat{M}(\theta_s - \theta_u)$ is decreasing in τ_p. At first, the transport development is beneficial only for skilled labors, who suffer from relatively low trade barriers. Then, unskilled labors also gains from trade by the further reduction of transport costs.

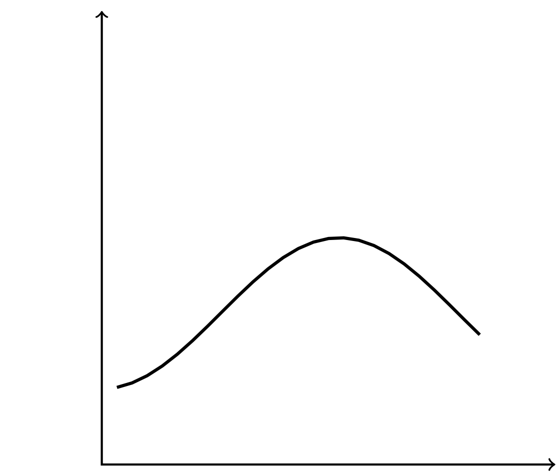

Figure 2: Transport cost and wage inequality.

3 Non Iceberg Specification

We have used the iceberg specification. However, it does not fully incorporate the idea that the cheap goods suffer from relatively high trade burdens. Then, we assume that τ_p units of the final goods is used to export one units of intermediate goods. Then, (5) is changed to

$$p_{hii} = w_h, \quad p_{hij} = (1 + \tau_t)(w_h + \tau_p) \quad \text{for } i \neq j \tag{10}$$

where we normalize the final goods to one. Here, the transport cost is specified symmetrically across sectors. Nevertheless, when $w_s > w_u$, transportation is costly for the unskilled.

Revenue distribution and resource constraint are changed because: (i) some revenue is distributed to final goods sector as transportation cost; (ii) labor is only used for the production of intermediate goods. Then, we replace (6) with

$$P_h Y_h = \sum_j p_{hij} x_{hij}, \quad L_h = \sum_j x_{hij} \tag{11}$$

The second equation denotes the resource constraint.

Now we can obtain two equations which determine the equilibrium. The first is the equation for the final goods price:

$$(\sum_h (\beta_h (w_h^{1-\rho} + (w_h + \tau_p)^{1-\rho})^{\frac{1-\epsilon}{1-\rho}})^{\frac{1}{1-\epsilon}} = 1 \tag{12}$$

The second is the equation for the relative labor demand. From (3), (4), (10) and (11),

$$\frac{\beta/L_s}{(1-\beta)/L_u} = \frac{H(w_s, \tau_p)}{H(w_s, \tau_p)} \quad \text{with} \quad H(w, \tau_p) \equiv \frac{(w^{1-\rho} + \hat{M}(w+\tau_p)^{1-\rho})^{\frac{\epsilon-\rho}{1-\rho}}}{w^{-\rho} + \hat{M}(w+\tau_p)^{-\rho}} \tag{13}$$

where $\hat{M} \equiv M(1+\tau_t)^{1-\rho}$ is trade openness. H is increasing in w (See appendix). Then, (12) and (13) imply the negative and the positive relationship between w_s and w_u respectively (see Figure 3).

The skill premium $\omega = \frac{w_s}{w_u}$ asymptotically reaches the value equivalent to the previous section: $\lim_{\tau_p \to 0} \omega = \lim_{\tau_p \to \infty} \omega = (\frac{\beta_s/L_s}{\beta_u/L_u})^{\frac{1}{\epsilon}}$. This is because the transport cost is not used in these cases.

The relative factor scarcity $\frac{\beta_s/L_s}{\beta_u/L_u}$ is important for determining the skill premium. From (13), skill premium is higher than one if and only if relative scarcity is higher than one: $\frac{\beta_s/L_s}{\beta_u/L_u} \gtreqless 1 \iff \omega \gtreqless 1$. For this reason, we assume

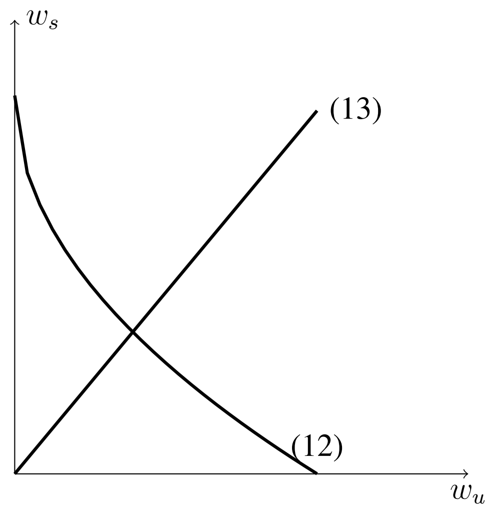

Figure 3: The equilibrium (w_s, w_u)

$\frac{\beta_s/L_s}{\beta_u/L_u} > 1$, which produces endogenous trade barrier differences.

Figure 4 plots computed values of $\omega(\tau_p)$.[3] The left hand side of the figure confirms the Kuznets curve. Moreover, in contrast to the previous section, with high transportation cost, the cost reduction implies lower wage inequality. This may be because some portion of the revenue is squeezed by the purchase of the final goods as the transport cost. Admittedly, this result is slightly different from the previous section. However, at the right, the behavior of $\omega(\tau_p)$ is modest and not so important because with high transport cost the effect of the trade is low.

(12) and (13) seem to be difficult to work analytically. However, if $\tau_p \approx 0$, we

[3]We choose $\epsilon = 2$ to match the elasticity of substitution across labors (Acemoglu (1998); Acemoglu and Autor (2011)) or across sectors with different skill intensities (Epifani and Gancia (2008)), and $\rho = 6$ to match the trade elasticity (Arkolakis et al. (2012)). We choose $\frac{\beta_s/L_s}{\beta_u/L_u} = 200$, $\beta_s = \beta_u = 0.5$, and $\hat{M} = 1$. We also examine the parameters $\rho = 4, 8$, $\frac{\beta_s/L_s}{\beta_u/L_u} = 2, 1600$, $\beta_s = 1 - \beta_u = 0.2, 0.8$, and $\hat{M} = 0.1, 6.0$. Although the quantitative result is changed considerably,the result is not changed qualitatively.

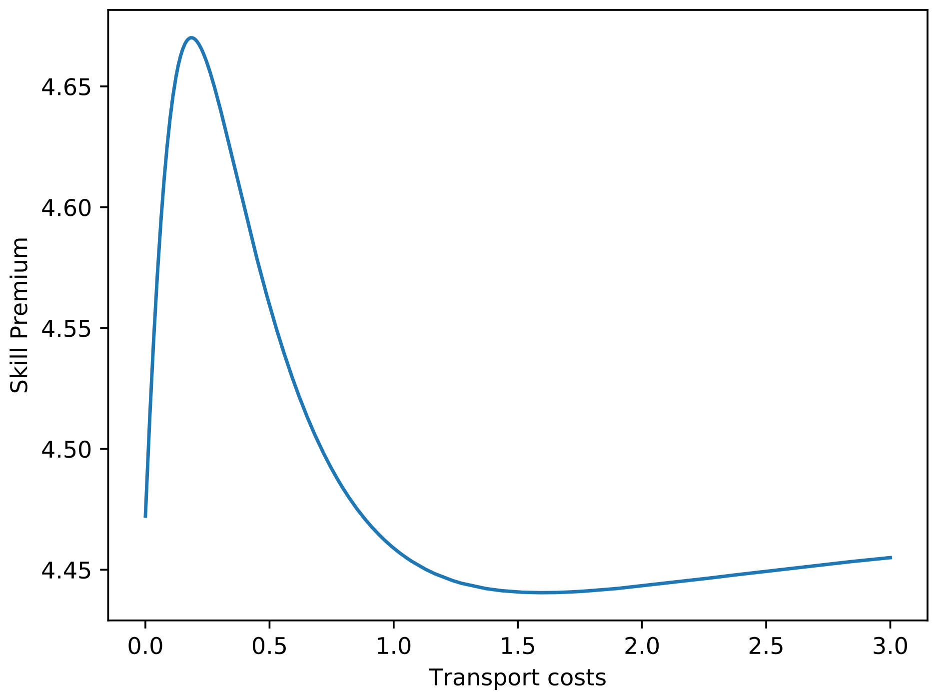

Figure 4: Skill Premium and Transportation Cost

can show $\omega(\tau_p)$ is increasing . From (13),

$$\frac{\beta_s/L_s}{\beta_u/L_u} = \frac{H(1, \frac{\tau_p}{w_s})}{H(1, \frac{\tau_p}{w_u})}\omega^{\epsilon} \tag{14}$$

Then, $\omega > (\frac{\beta_s/L_s}{\beta_u/L_u})^{\frac{1}{\epsilon}}$ if and only if $H(1, \frac{\tau_p}{w_s}) < H(1, \frac{\tau_p}{w_u})$. Since $\frac{\tau_p}{w_h(\tau_p)} \approx 0$ for $\tau_p \approx 0$ and $\frac{\tau_p}{w_s} < \frac{\tau_p}{w_u}$, it is only needed to show $\frac{\partial}{\partial \tau_p} H(1, \tau_p) > 0$ at $\tau_p = 0$. This is indeed the case because $\frac{\partial \log H(1,0)}{\partial \tau_p} = \epsilon \frac{\hat{M}}{1+\hat{M}} > 0$.

4 Conclusion

This paper begins with the presumption that the unskilled intensive goods are hampered by higher transport cost by their low values. Although the model in this paper is quite simple, many insights can be obtained: (i) The development of the transportation infrastructure produces Kuznets curve; (ii) Trade liberalization increases wage inequality and its effect is also increasing.

Moreover, these results have many policy implications. First, since the effect of the trade liberalization is nonlinear, the information from the previous liberalization may not be informative. Second, investments in the transportation infrastructure can change wage inequality. Especially, if the size of the investment is sufficiently large, it can reduce wage inequality.

References

ACEMOGLU, D. (1998): "Why do new technologies complement skills? Directed technical change and wage inequality," *Quarterly journal of economics*, 113, 1055–1089.

ACEMOGLU, D. AND D. AUTOR (2011): "Skills, tasks and technologies: Implications for employment and earnings," *Handbook of labor economics*, 4, 1043–1171.

ALCHIAN, A. A. AND W. R. ALLEN (1972): "University economics", Wadsworth Publishing Company; 3rd edition.

ARKOLAKIS, C., A. COSTINOT, AND A. RODRÍGUEZ-CLARE (2012): "New trade models, same old gains?" *American Economic Review*, 102, 94–130.

ARMINGTON, P. S. (1969): "A theory of demand for products distinguished by place of production," *IMF Staff Papers*, 16, 159–178.

BANERJEE, A., E. DUFLO, AND N. QIAN (2012): "On the road: Access to transportation infrastructure and economic growth in China," *NBER Working Paper*.

BERNARD, A., B. JENSEN, S. REDDING, AND P. SCHOTT (2012): "The empirics of firm heterogeneity and international trade," *Annual Review of Economics*, 4, 283–313.

BERNARD, A. B. AND J. B. JENSEN (1995): "Exporters, jobs, and wages in US manufacturing: 1976-1987," *Brookings papers on economic activity*, 1995, 67–119.

DONALDSON, D. (2010): "Railroads of the Raj: Estimating the impact of transportation infrastructure," *NBER Working Paper*.

DONALDSON, D. AND R. HORNBECK (2016): "Railroads and American economic growth: A market access approach," *Quarterly Journal of Economics*, 131, 799–858.

EPIFANI, P. AND G. GANCIA (2008): "The Skill Bias of World Trade," *Economic Journal*, 118, 927–960.

FEENSTRA, R. (1988): "Quality change under trade restraints in Japanese autos," *The Quarterly Journal of Economics*, 103, 131–146.

GOLDBERG, P. K. AND N. PAVCNIK (2007): "Distributional effects of globalization in developing countries," *Journal of economic Literature*, 45, 39–82.

HANSON, G. H. AND C. XIANG (2004): "The home-market effect and bilateral trade patterns," *American Economic Review*, 94, 1108–1129.

HUMMELS, D. AND A. SKIBA (2004): "Shipping the good apples out? An empirical confirmation of the Alchian-Allen conjecture," *Journal of political Economy*, 112, 1384–1402.

IRARRAZABAL, A., A. MOXNES, AND L. D. OPROMOLLA (2015): "The tip of the iceberg: a quantitative framework for estimating trade costs," *Review of Economics and Statistics*, 97, 777–792.

KRUGMAN, P. (2000): "Technology, trade and factor prices," *Journal of international Economics*, 50, 51–71.

KUZNETS, S. (1955): "Economic growth and income inequality," *American economic review*, 45, 1–28.

LIMAO, N. AND A. VENABLES (2001): "Infrastructure, geographical disadvantage, transport costs, and trade," *World Bank Economic Review*, 15, 451–479.

LUGOVSKYY, V. AND A. SKIBA (2015): "How geography affects quality," *Journal of Development Economics*, 115, 156–180.

VERHOOGEN, E. (2008): "Trade, quality upgrading, and wage inequality in the Mexican manufacturing sector," *Quarterly Journal of Economics*, 123, 489–530.

WAUGH, M. (2010): "International trade and income differences," *American Economic Review*, 100, 2093–2124.

A The Sign of $\frac{d^2\omega}{d(\ln \hat{M})^2}$

What we want to show that if the skilled import share is lower than 50 percent, then $\frac{d^2\omega}{d(\ln \hat{M})^2}$ is positive. The first step is to write the import share of h intensive sector as $\lambda(x_h) \equiv \frac{x_h}{x_h+1}$ where $x_h \equiv \hat{M}(1+\theta_h \tau_p)^{1-\rho}$. Since $\lambda'(x) > 0$, the skilled import shares

$$\lambda(x_h) < 0.5 \iff x_h < 1 \tag{15}$$

The next step is to see that $\frac{d^2 \log \omega}{d(\ln \hat{M})^2} > 0$ is satisfied if and only if

$$\phi(x_s) > \phi(x_u) \tag{16}$$

where $\phi(x) \equiv \frac{x}{(1+x)^2}$. Then, we only need to show that if $x_u < x_s \leq 1$, then $\phi(x_s) > \phi(x_u)$. This is indeed satisfied because $\phi'(x) > 0$ for $x \leq 1$. $\square$

B The Sign of $\frac{\partial H}{\partial w}$

$\frac{\partial \log H}{\partial w} = (\epsilon - \rho)\frac{h(-\rho)}{h(1-\rho)} + \rho\frac{h(-\rho-1)}{h(-\rho)}$ where $h(\rho) \equiv w^{\rho} + (w + \tau_p)^{\rho}$. It implies

$$\frac{\partial H}{\partial w} > 0 \quad \text{if} \quad h(-\rho-1)h(1-\rho) - h^2(-\rho) > 0$$

This condition is indeed satisfied because $-\rho = \frac{1}{2}(-\rho-1) + \frac{1}{2}(1-\rho)$ and h is log convex: $\frac{\partial^2 \log h(\rho)}{\partial \rho^2} = \frac{w^{\rho}(w+\tau_p)^{\rho}(\log w - \log(w+\tau_p))^2}{w^{\rho}+(w+\tau_p)^{\rho}} > 0$. Then, $\frac{\partial H}{\partial w} > 0$. $\square$