Intergenerational Bargaining in Technology Adoption

Work in Progress

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1. Introduction

I study the society-wide choice of technology adoption in an environment where human capital is transmitted from the old to the young generation but the young generation can opt out for experimenting with the society-sanctioned technology. The adoption of new technology raises the return from experiment and thereby benefits the young and future generations while the old generation loses due to the depreciation in the market value of existing human capital. The choice of technology adoption is made in each period in an inter-generational bargaining. Bargaining is efficient: new technology is adopted if and only if it raises the joint-utility of the current old and young generations. Since technology adoption benefits future generations, there is an inherent bias toward preserving current technology. I examine two variations of the environment, exogenous and endogenous technological change. In the former, new technology expands continuously, raising the value of experiment. Conservation of current technology is not sustainable and new technology is adopted at all times. In the latter, new technology is a fixed expansion of the current technology. This implies that conserving the current technology permanently reduces the value of experiment for the future generations. Conservation of current technology is sustainable if the fraction of old generation who would lose from adopting new technology is large enough. As of now, I have made an (incomplete) attempt at modeling these ideas. The eventual goal is to use the model in understanding the medium to long-term growh episodes such as transition countries in the 1990's, the aftermath of the Asian debt crisis in late 1990's, and the stagnation of old civilizations such as China after the Sung Dynasty period.

2. The Model Economy

There are two overlapping generations in each period. The population of each generation is normalized to one. Let $G(h)$ denote the distribution of human capital within the old generation. The young generation is endowed with no human capital. Production takes place on an individual basis or in a team of two people, one from each generation. An old person with human capital h alone produces ϕh units of output. A team of an old person with human capital h produces h units of output. Within a team, the young person inherits the human capital of the old person in the next period. A young person alone produces θh units of output, where h is his human capital drawn from the distribution function $\tilde{F}(h)$; he carries the human capital to the next period. Function $\tilde{F}$ represents the technology currently in use, and depends on the society-wide choice of technology adoption: $\tilde{F} \in \{\hat{F}, \check{F}\}$ where $\hat{F}$ is the frontier technology available for adoption and $\check{F}$ is the technology used in the previous period. Let $S \equiv (\hat{F}, \check{F}, G)$, $\tilde{S} \equiv (S, \tilde{F})$, $\hat{S} \equiv (S, \hat{F})$, and $\check{S} \equiv (S, \check{F})$. Let the choice of technology adoption be given by $\Gamma(S)$: $\Gamma(S) = \hat{F}$ if the available technology is adopted; $\Gamma(S) = \check{F}$ if not. The utility of an old person with human capital h is:

$$V_o(h; \tilde{S}, \Gamma) = \max \left\{ \phi h, h - w(h; \tilde{S}, \Gamma) \right\}, \tag{1}$$

where $w(h; \tilde{S}, \Gamma)$ is the payment to the young person in the match. The utility of a young person matched with an old person with human capital h is:

$$V_y(h; \tilde{S}, \Gamma) = w(h; \tilde{S}, \Gamma) + \beta V_o(h; \Lambda\tilde{S}(\tilde{S}, \Gamma), \Gamma), \tag{2}$$

where β is the discount rate and Λ denotes one-period updating of the immediately following function: $\Lambda S(\tilde{S}, \Gamma) \equiv (\Lambda\hat{F}, \tilde{F}, \Lambda G(\tilde{S}, \Gamma)$ and $\Lambda\tilde{S}(\tilde{S}, \Gamma) \equiv (\Lambda S(\tilde{S}, \Gamma), \Gamma(\Lambda S(\tilde{S}, \Gamma)))$. The utility of a lone young person is:

$$\tilde{V}_y(\tilde{S}, \Gamma) = \int \left(\theta h + \beta V_o(h; \Lambda\tilde{S}(\tilde{S}, \Gamma), \Gamma) \right) d\tilde{F}(h). \tag{3}$$

Matching is frictionless, so the payment schedule $w(h)$ must equalize the ex-ante utilities of all young people:

$$V_y(h; \tilde{S}, \Gamma) = \tilde{V}_y(\tilde{S}, \Gamma) \tag{4}$$

for all h. From (1) to (4), observe that there is $\bar{h}(\tilde{S}, \Gamma)$ below which an old person produces alone and above which he produces with a young person. Further, we have

$$w(\bar{h}(\tilde{S}, \Gamma); \tilde{S}, \Gamma) = (1 - \phi) \cdot \bar{h}(\tilde{S}, \Gamma), \tag{5}$$

$$w(h_1; \tilde{S}, \Gamma) = w(h_2; \tilde{S}, \Gamma) - \beta(h_1 - h_2) \cdot \left(\frac{1 - \beta^t}{1 - \beta} + \beta^t \phi \right) \tag{6}$$

for $h_1, h_2 \in (\bar{h}(\Lambda^t \tilde{S}(\tilde{S}, \Gamma)), \bar{h}(\Lambda^{t+1} \tilde{S}(\tilde{S}, \Gamma)))$, and

$$w(h_1; \tilde{S}, \Gamma) = w(h_2; \tilde{S}, \Gamma) - \frac{\beta(h_1 - h_2)}{1 - \beta} \tag{7}$$

for $h_1, h_2 > \lim_{t \to \infty} \bar{h}(\Lambda^t \tilde{S}(\tilde{S}, \Gamma))$. Distribution function G evolves according to:

$$\Lambda G(\tilde{S}, \Gamma)(h) = G(\bar{h}(\tilde{S}, \Gamma)) \cdot \tilde{F}(h) \tag{8}$$

for $h < \bar{h}(\tilde{S}, \Gamma)$; and

$$\Lambda G(\tilde{S}, \Gamma)(h) = G(\bar{h}(\tilde{S}, \Gamma)) \cdot \tilde{F}(h) + G(h) - G(\bar{h}(\tilde{S}, \Gamma)) \tag{9}$$

for $h \geq \bar{h}(\tilde{S}, \Gamma)$. The choice of technology adoption is determined by sequential intergenerational bargaining. Bargaining is efficient in that it maximizes the joint surplus:

$$\Gamma(S) = \arg\max_{\tilde{S}} \left\{ \tilde{V}_y(\tilde{S}, \Gamma) + \int V_o(h; \tilde{S}, \Gamma) dG(h) \right\}. \tag{10}$$

Given the law of motion for the frontier technology $\Lambda \hat{F}$, an equilibrium is the technology adoption function Γ, the value functions V_o, V_y, and $\tilde{V}_y$, the threshold human capital function $\bar{h}$, the payment schedule w, and the law of motion for human capital distribution ΛG that together satisfy (1) to (10).

2.1 One New Technology: Institutional Change

Consider the opportunity for adopting a single new technology: $\Lambda\hat{F} = \hat{F}$. Given S, suppose that the new technology will be adopted next period if not adopted in this period: $\Gamma(\Lambda S(\check{S},\Gamma)) = \hat{F}$. From (1) to (4), observe that $V_o(h;\tilde{S},\Gamma)$, $V_y(h;\tilde{S},\Gamma)$, $\tilde{V}_y(\tilde{S},\Gamma)$, $\bar{h}(\tilde{S},\Gamma)$, and $w(h;\tilde{S},\Gamma)$ would be independent of G, so the threshold level of human capital would be constant once the new technology is adopted: $\bar{h}(\check{S},\Gamma) < \bar{h}(\hat{S},\Gamma) = \bar{h}(\Lambda^t\tilde{S}(\hat{S},\Gamma),\Gamma) = \bar{h}(\Lambda^t\tilde{S}(\check{S},\Gamma),\Gamma)$ for all t. From (5) to (7), we have $w(\bar{h}(\hat{S},\Gamma);\hat{S},\Gamma) = (1-\phi)\cdot\bar{h}(\hat{S},\Gamma)$ and $w(\bar{h}(\check{S},\Gamma);\check{S},\Gamma) = (1-\phi)\cdot\bar{h}(\check{S},\Gamma)$ so that the young generation's gain from adoption is $\Delta\tilde{V}_y(S,\Gamma) \equiv \tilde{V}_y(\hat{S},\Gamma) - \tilde{V}_y(\check{S},\Gamma) = (1-\phi+\beta\phi)(\bar{h}(\hat{S},\Gamma)-\bar{h}(\check{S},\Gamma))$. Further, $w(h_1;\hat{S},\Gamma) = w(h_2;\hat{S},\Gamma)-\beta(h_1-h_2)/(1-\beta)$ for $h_1,h_2 > \bar{h}(\hat{S},\Gamma)$; $w(h_1;\check{S},\Gamma) = w(h_2;\check{S},\Gamma)-\beta\phi(h_1-h_2)$ for $h_1,h_2 \in [\bar{h}(\check{S},\Gamma),\bar{h}(\hat{S},\Gamma)]$; and $w(h_1;\check{S},\Gamma) = w(h_2;\check{S},\Gamma)-\beta(h_1-h_2)/(1-\beta)$ for $h_1,h_2 \geq \bar{h}(\hat{S},\Gamma)$ so that the old generation's loss from adoption is $\Delta V_o(S,\Gamma) \equiv \int(V_o(h;\check{S},\Gamma) - V_o(h;\hat{S},\Gamma))dG(h) = (1-\phi+\beta\phi)(\bar{h}(\hat{S},\Gamma)-\bar{h}(\check{S},\Gamma))\cdot\tilde{G}(\bar{h}(\check{S},\Gamma),\bar{h}(\hat{S},\Gamma))$, where $\tilde{G}(h_1,h_2) \equiv 1-G(h_2)+\int_{h_1}^{h_2}(h-h_1)/(h_2-h_1)dG(h) < 1$. Therefore, $\Delta\tilde{V}_y(S,\Gamma) > \Delta V_o(S,\Gamma)$ and $\Gamma(S) = \hat{F}$ from (10). This implies that the new technology is adopted immediately if it will ever be adopted: $\Gamma(S) = \hat{F}$ if $\Gamma(\Lambda^t S(\check{S},\Gamma)) = \hat{F}$ for any t. As a corollary, the adoption-always rule, i.e., $\Gamma(S) = \hat{F}$ for all S, is an equilibrium.

Now suppose that the new technology will never be adopted if not adopted in this period: $\Gamma(\Lambda^t S(\check{S},\Gamma)) = \check{F}$ for all t. From (1) to (4), $\bar{h}(\check{S},\Gamma) = \bar{h}(\Lambda^t\tilde{S}(\check{S},\Gamma),\Gamma) < \bar{h}(\hat{S},\Gamma) = \bar{h}(\Lambda^t\tilde{S}(\hat{S},\Gamma),\Gamma)$ for all t. From (5) to (7), we have $w(\bar{h}(\hat{S},\Gamma);\hat{S},\Gamma) = (1-\phi)\cdot\bar{h}(\hat{S},\Gamma)$ and $w(\bar{h}(\check{S},\Gamma);\check{S},\Gamma) = (1-\phi)\cdot\bar{h}(\check{S},\Gamma)$ so that $\Delta\tilde{V}_y(S,\Gamma) = (1-\phi+\beta\phi)(\bar{h}(\hat{S},\Gamma)-\bar{h}(\check{S},\Gamma))$ as above. Further, $w(h_1;\hat{S},\Gamma) = w(h_2;\hat{S},\Gamma)-\beta(h_1-h_2)/(1-\beta)$ for $h_1,h_2 > \bar{h}(\hat{S},\Gamma)$ and $w(h_1;\check{S},\Gamma) = w(h_2;\check{S},\Gamma)-\beta(h_1-h_2)/(1-\beta)$ for $h_1,h_2 \geq \bar{h}(\check{S},\Gamma)$ so that $\Delta V_o(S,\Gamma) = (1-\phi+\beta\phi)/(1-\beta)\cdot(\bar{h}(\hat{S},\Gamma)-\bar{h}(\check{S},\Gamma))\cdot\tilde{G}(\bar{h}(\check{S},\Gamma),\bar{h}(\hat{S},\Gamma))$. Therefore, $\Delta V_o(S,\Gamma) > \Delta\tilde{V}_y(S,\Gamma)$ if and only if $\tilde{G}(\bar{h}(\check{S},\Gamma),\bar{h}(\hat{S},\Gamma)) > 1-\beta$. The intuition for the fraction $1-\beta$ is that the capital loss to an old person, i.e., the rise in the payment following the adoption of the new technology, is smaller than the gain by a young person since the young person would face the same capital loss, albeit discounted, in the next period. In other words, the gains are distributed among all future generations while the loss is concentrated among the current old generation. The implication is that the old technology could be conserved if and only if a sufficient fraction of the old generation stays above the threshold level of human capital for team production over time. From (8) and (9), note that $\tilde{G}(\bar{h}((\Lambda S(\check{S},\Gamma),\check{F}),\Gamma),\bar{h}((\Lambda S(\check{S},\Gamma),\hat{F}),\Gamma) > 1-\beta$ if $\tilde{G}(\bar{h}(\check{S},\Gamma),\bar{h}(\hat{S},\Gamma)) > 1-\beta$. Therefore, a conditional-adoption rule, i.e., $\Gamma(S) = \hat{F}$ if $\tilde{G}(\bar{h}(\check{S},\Gamma),\bar{h}(\hat{S},\Gamma)) \leq 1-\beta$ and $\Gamma(S) = \check{F}$ otherwise, is an equilibrium.

2.2 Exogenous Technological Change: Decentral Policy Making

Now consider the scenario of the frontier technology advancing at a constant rate λ: $\Lambda\hat{F}(h) = \hat{F}(h/\lambda)$. Given S, suppose that new technology will be adopted in all future periods: $\Gamma(\Lambda^t S(\hat{S},\Gamma)) = \Gamma(\Lambda^t S(\check{S},\Gamma)) = \Lambda^t\hat{F}$. From (1) to (4), observe that $V_o(h;\tilde{S},\Gamma)$, $V_y(h;\tilde{S},\Gamma)$, $\tilde{V}_y(\tilde{S},\Gamma)$, $\bar{h}(\tilde{S},\Gamma)$, and $w(h;\tilde{S},\Gamma)$ are independent of G under this rule. Since $V_o(h;\hat{S},\Gamma)$ is increasing in h, $\tilde{V}_y(\hat{S},\Gamma) > \tilde{V}_y(\check{S},\Gamma)$ and $\bar{h}(\hat{S},\Gamma) > \bar{h}(\check{S},\Gamma)$. From (5) to (7), we have $w(\bar{h}(\hat{S},\Gamma);\hat{S},\Gamma) = (1-\phi)\cdot\bar{h}(\hat{S},\Gamma)$ and $w(\bar{h}(\check{S},\Gamma);\check{S},\Gamma) = (1-\phi)\cdot\bar{h}(\check{S},\Gamma)$ so that $\Delta\tilde{V}_y(S,\Gamma) = (1-\phi+\beta\phi)(\bar{h}(\hat{S},\Gamma)-\bar{h}(\check{S},\Gamma))$ as in Section 2.1. Similarly, $w(h_1;\check{S},\Gamma) = w(h_2;\check{S},\Gamma) - \beta\phi(h_1-h_2)$ for $h_1,h_2 \in [\bar{h}(\check{S},\Gamma),\bar{h}(\hat{S},\Gamma)]$ and $w(h_1;\hat{S},\Gamma) - w(h_2;\hat{S},\Gamma) = w(h_1;\check{S},\Gamma) - w(h_2;\check{S},\Gamma)$ for $h_1,h_2 > \bar{h}(\hat{S},\Gamma)$ so that $\Delta V_o(S,\Gamma) = (1-\phi+\beta\phi)(\bar{h}(\hat{S},\Gamma)-\bar{h}(\check{S},\Gamma))\cdot\tilde{G}(\bar{h}(\check{S},\Gamma),\bar{h}(\hat{S},\Gamma))$. Therefore, $\Delta\tilde{V}_y(S,\Gamma) > \Delta V_o(S,\Gamma)$ and, from (10), the adoption-always rule, i.e., $\Gamma(S) = \hat{F}$ for all S, is an equilibrium.

Now, given S, suppose that there will never be an adoption of a new technology: $\Gamma(S) = \Gamma(\Lambda^t S(\check{S},\Gamma)) = \check{F}$. From (1) to (4), we have $\tilde{V}_y((\Lambda^t S(\check{S},\Gamma),\Lambda^t\hat{F}),\Gamma) + \int V_o(h;(\Lambda^t S(\check{S},\Gamma),\Lambda^t\hat{F}),\Gamma)d\Lambda^t G(h;\check{S},\Gamma) > \int h(\theta+\beta\phi)d\Lambda^t\hat{F}(h) > \tilde{V}_y((\Lambda^t S(\check{S},\Gamma),\check{F}),\Gamma) + \int V_o(h;(\Lambda^t S(\check{S},\Gamma),\check{F}),\Gamma)d\Lambda^t G(h;\check{S},\Gamma)$ for some t. Therefore, given any S, there will be an adoption of a new technology at some point.

2.3 Endogenous Technological Change: Central Policy Making

Now consider the scenario of the frontier technology, instead of expanding automatically, is an innovation of the current technology at a fixed rate λ: $\hat{F}(h) = \check{F}(h/\lambda)$ and $\Lambda\hat{F}(h) \equiv \tilde{F}(h/\lambda)$. Given S, suppose that new technology will be adopted in all future periods: $\Gamma(\Lambda^t S(\hat{S},\Gamma)) = \Lambda^t\hat{F}$ and $\Gamma(\Lambda^t S(\check{S},\Gamma)) = \Lambda^{t-1}\hat{F}$. From (1) to (4), $\tilde{V}_y(\hat{S},\Gamma) > \tilde{V}_y(\check{S},\Gamma)$; $V_o(h;\hat{S},\Gamma) - V_o(h;\check{S},\Gamma) = 0$ for $h \leq \bar{h}(\check{S},\Gamma)$; and $V_o(h;\hat{S},\Gamma) - V_o(h;\check{S},\Gamma) = (\tilde{V}_y(\hat{S},\Gamma) - \tilde{V}_y(\check{S},\Gamma))((1-\lambda^t\beta^t)/(1-\lambda\beta) + \lambda^t\beta^t(h-\lambda^t\bar{h}(\check{S},\Gamma))/(\lambda^{t+1}\bar{h}(\check{S},\Gamma) - \lambda^t\bar{h}(\check{S},\Gamma)))$ for $h \in (\lambda^t\bar{h}(\check{S},\Gamma), \lambda^{t+1}\bar{h}(\check{S},\Gamma))$. Note that that the larger amount of human capital an old person has, the greater his loss from technology adoption is. Summing up over h, we obtain $\Delta\tilde{V}_y(S,\Gamma) > \Delta V_o(S,\Gamma)$ if and only if $\sum_{t=0}^{\infty}\{\int_{\lambda^t\bar{h}(\check{S},\Gamma)}^{\lambda^{t+1}\bar{h}(\check{S},\Gamma)}((1-\lambda^t\beta^t)/(1-\lambda\beta) + \lambda^t\beta^t(h - \lambda^t\bar{h}(\check{S},\Gamma))/(\lambda^{t+1}\bar{h}(\check{S},\Gamma) - \lambda^t\bar{h}(\check{S},\Gamma)))dG(h)\} < 1$. Roughly speaking, the inequality holds only if the average human capital of the old generation is at a sufficiently low level relative to the reservation level for team production. Therefore, the adoption-always rule, i.e., $\Gamma(S) = \hat{F}$ for all S, is not an equilibrium.

Now, given S, suppose that technology will be conserved in all future periods: $\Gamma(\Lambda^t S(\hat{S},\Gamma)) = \hat{F}$ and $\Gamma(\Lambda^t S(\check{S},\Gamma)) = \check{F}$ for all S. Following the reasning in Section 2.1, $\Delta V_o(S,\Gamma) > \Delta\tilde{V}_y(S,\Gamma)$ if and only if $\tilde{G}(\bar{h}(\check{S},\Gamma), \bar{h}(\hat{S},\Gamma)) > 1-\beta$. The inequality holds only if the average human capital of the old generation is at a sufficietly high level relative to the reservation level for team production. Therefore, the adoption-never rule, i.e., $\Gamma(S) = \check{F}$ for all S, is not an equilibrium.

Now, given S, suppose that adopting technology in this period leads to perpetual adoption and conserving technology in this period leads to perpetual conservation: $\Gamma(\Lambda^t S(\hat{S},\Gamma)) = \Lambda^t\hat{F}$ and $\Gamma(\Lambda^t S(\check{S},\Gamma)) = \check{F}$ for all t. From (5) to (7), we have $\Delta\tilde{V}_y(S,\Gamma) = (1-\phi+\beta\phi)(\bar{h}(\hat{S},\Gamma) - \bar{h}(\check{S},\Gamma))$. Further, $\Delta V_o(S,\Gamma) = \Delta\tilde{V}_y(S,\Gamma)\breve{G}(\bar{h}(\check{S},\Gamma), \bar{h}(\hat{S},\Gamma))/(1-\beta)$, where $\breve{G}(h_1,h_2) \equiv \tilde{G}(h_1,h_2) + \beta(\lambda-1)h_2/(h_2-h_1)\cdot\sum_{t=0}^{\infty}\{\int_{\lambda^t h_2}^{\lambda^{t+1}h_2}((1-\lambda^t\beta^t)/(1-\lambda\beta) + \lambda^t\beta^t(h-\lambda^t h_2)/(\lambda^{t+1}h_2 - \lambda^t h_2))dG(h)\} < 1$ Therefore, $\Delta V_o(S,\Gamma) > \Delta\tilde{V}_y(S,\Gamma)$ if and only if $\breve{G}(\bar{h}(\check{S},\Gamma), \bar{h}(\hat{S},\Gamma)) > 1-\beta$. From (8) and (9), note that $\breve{G}(\bar{h}((\Lambda S(\check{S},\Gamma),\check{F}),\Gamma), \bar{h}((\Lambda S(\check{S},$

$\Gamma), \hat{F}), \Gamma)) > 1-\beta$ if $\breve{G}(\bar{h}(\check{S},\Gamma), \bar{h}(\hat{S},\Gamma)) > 1-\beta$. Assume further that $\breve{G}(\bar{h}((\Lambda S(\check{S},\Gamma), \check{F}), \Gamma), \bar{h}((\Lambda S(\check{S},\Gamma), \hat{F}), \Gamma)) \leq 1-\beta$ if $\breve{G}(\bar{h}(\check{S},\Gamma), \bar{h}(\hat{S},\Gamma)) \leq 1-\beta$. Under this monotonicity condition, a conditional-adoption rule, i.e., $\Gamma(S) = \hat{F}$ if $\breve{G}(\bar{h}(\check{S},\Gamma), \bar{h}(\hat{S},\Gamma)) \leq 1-\beta$ and $\Gamma(S) = \check{F}$ otherwise, is an equilibrium.

2.4. Generational Transfers

Now reconsider the model with generational transfer. Let $\tau(S,\tilde{S},\Gamma)$ denote the per-capital transfer from the young to the old generation, and replace (1) to (3) with

$$V_o(h;\tilde{S},\Gamma) = \max\left\{\phi h, h - w(h;\tilde{S},\Gamma)\right\} + \tau(\tilde{S},\Gamma), \tag{11}$$

$$V_y(h;\tilde{S},\Gamma) = w(h;\tilde{S},\Gamma) + \beta V_o(h;\Delta\tilde{S}(\tilde{S},\Gamma),\Gamma) - \tau(\tilde{S},\Gamma), \tag{12}$$

and

$$\tilde{V}_y(\tilde{S},\Gamma) = \int \Big(\theta h + \beta V_o(h;\Delta\tilde{S}(\tilde{S},\Gamma),\Gamma)\Big)\, d\tilde{F}(h) - \tau(\check{S},\Gamma). \tag{13}$$

Let $W_o(h;\tilde{S},\Gamma) \equiv V_o(h;\tilde{S},\Gamma) - \tau(\tilde{S},\Gamma)$ and $\tilde{W}_y(\tilde{S},\Gamma) \equiv \tilde{V}_y(\tilde{S},\Gamma) + \tau(\tilde{S},\Gamma)$. The transfer is determined by

$$\frac{\tilde{V}_y(\tilde{S},\Gamma) - (\rho\tilde{W}_y(\hat{S},\Gamma) + (1-\rho)\tilde{W}_y(\check{S},\Gamma))}{\int (V_o(h;\tilde{S},\Gamma) - (\rho W_o(h;\hat{S},\Gamma) + (1-\rho)W_o(h;\check{S},\Gamma)))dG(h)} = \frac{\sigma}{1-\sigma}, \tag{14}$$

where ρ can be interpreted as the default probability of technology adoption and σ as the share of surplus that accrues to the young generation. From (11), (13), and (14), we have

$$\begin{aligned}
\tau(\hat{S},\Gamma) &= (1-\rho)\left\{(1-\sigma)(\tilde{W}_y(\hat{S},\Gamma) - \tilde{W}_y(\check{S},\Gamma)) + \sigma\int (W_o(h;\check{S},\Gamma) - W_o(h;\hat{S},\Gamma))dG(h)\right\}; \\
\tau(\check{S},\Gamma) &= \quad -\rho \quad \left\{(1-\sigma)(\tilde{W}_y(\hat{S},\Gamma) - \tilde{W}_y(\check{S},\Gamma)) + \sigma\int (W_o(h;\check{S},\Gamma) - W_o(h;\hat{S},\Gamma))dG(h)\right\}.
\end{aligned} \tag{15}$$

Thus (some of) the results in Sections 2.1 to 2.3 can be viewed as valid under special cases: $\rho = 1$ for the the adoption-always rule and $\rho = 0$ for the adoption-never rule. In general, note that the transfer payment increases on the young generation's gain from technology aoption and/or the old generation's loss from it. Futher, the joint utility of the current young and old generations includes the discounted value of the transfer payment that the young generation expects when they get old. We can entertain the following conjecture. In the case of the exogenous technological change, the next period's utility gain/loss from technology adoption is higher if the old technology is maintained in the current period. The transfer payment would then act against the adoption-always rule since the payment that the young generation expects to receive when they get old would be higher if the old technology is maintained in the current period. Also, the transfer payment would act against the adoption-never rule since the payment that the young generation expects to pay when they get old would be higher if the old technology is maintained in the current period. In the case of endogenous technological change, the effect of this period's adoption decision on next period's gain/loss from technology adoption is mitigated, and so is the effect of the transfer payment on those rules.