Ignorance is Bliss

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Abstract

An agent who expects her preferences to change with the passage of time may try to constrain her future actions. We use this well-known idea to explain why a person or even an entire society may reject technological progress. Our explanation is that a low-wage career means that a person spends more time at home, and that this commitment may more than compensate her for the lower lifetime income.

1 Introduction

Strotz (1955) pointed out that if their preferences are not time-consistent, people will try to constrain their future actions. We use his insight to explain why a society may reject a good technology in favor of a bad one. The intuition is this: If a farmer moves to the city, he will earn a higher hourly wage, but this will keep him at work longer and leave him with less time for his family which will then face an unwelcome change of life-style. The prospect of all this may convince him to remain on the farm so as to ensure that he will spend more time at home. The result survives even in a group – a village, say – in which people can use the high earnings that a modern technology affords to hire others to provide child care and other home goods. The results hinge on the assumption that the farmer cannot commit *directly* to a limited market participation, and that this pushes him into using a bad technology as a commitment device[1].

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[1]Even in parts of the U.S. today, technology is used as a commitment device. For example, the Amish, an Annabaptist sect found these days mainly in Pennsylvania, reject mechanized farm technology and limit their participation in outside labor markets in order to maintain their family and religious values.

These results help us understand inequality in two ways. First, they explain why one may reject a new, better technology even if it is available for *free*. The usual explanation for technological inertia is explicit and implicit adoption costs – investments made in past technologies in the form of machines and training. A nice example along these lines is Zeira (1998) who notes that new technology tends to be labor-saving, and that therefore poor countries, being labor abundant, will be the last to adopt such technology and that this fact magnifies productivity differentials. And Ueda (1999) argues that a switch to a modern technology may sever one's ties to the community and reduce one's ability to insure against risk. And not least, vintage capital models imply that when capital is technology-specific, it is optimal to switch technologies only periodically because switching devalues the old capital. This class of models does not explain why countries spend resources on keeping technology out – Japan and China for centuries banned trade with foreigners; some poor countries tax the imports of machinery that embodies new technology and limit activities of foreign companies.

Second, our results hold for a group of homogeneous individuals. The usual explanation for a hostility towards new technology is that a group such as the Luddites in early 19th century Lancashire stands to lose by its introduction, and therefore resists it at the expense of the rest of society. Krusell and Rios-Rull (1996) show that a democracy will reject technological progress when it destroys the skills of the majority. Parente and Prescott (forthcoming) show that monopoly rights can shut out a new technology. These arguments invoke heterogeneity, as does the argument that one cannot import new technology in e.g., India, because of the myriad of bribes and license fees that one has to pay in order to get started.

In sum, we explain technological inertia and resistance to progress without invoking adoption costs or heterogeneity of agents. We instead explain inertia and resistance to technology in terms of the role that technology plays as a commitment device.

Carillo and Mariotti (forthcoming) have already shown, and under a wider class of utility functions, that time inconsistent preferences can lead to a rejection of information, and more recently other papers have argued a similar point. We move beyond their framework when we show how the rejection of new technology relates to the elasticity of labor supply and, more importantly, model the multi-agent equilibrium. In equilibrium, more and more people switch to the modern technology as it improves with time and the development process ends in a productivity miracle. The equilibrium has features that help interpret historical facts on development: health decline in Britain and the US during industrialization, rise and fall of income inequality of the Kuznets type and self-imposed economic isolation in medieval China and Japan.

2 A one-agent economy

An agent lives for three periods, labelled 1, 2, and 3. At date 1 the agent chooses a market production technology α from an exogenously given menu, the interval $[0, A]$. She produces only in period 2, when she has one unit of time that can be used to produce two goods: a market good, y, consumed at date 2, and a home good, h, consumed at date 3. The home good is therefore the outcome of an investment that takes one period to mature, a delay that seems to make sense when h is health or the quality of one's children. The state of technology in the home good sector is fixed and not subject to choice.

Production possibilities: The agent has a unit of time at her disposal in period 2 only. Let x be the time that the agent devotes to producing y, which leaves her with $1 - x$ units of time to invest in h. The production functions are

$$y = \alpha x$$

for the market good, and, after choosing units appropriately,

$$h = 1 - x$$

for the home good. The market technology α is endogenous, however, and must be chosen one period in advance, perhaps because some training is required. The training delay prevents the agent from revising her choice of technology in period 2 in time to produce with it. This means that the technology choice is irreversible, but α is certainly disposable.

Preferences: We use a special case of preferences that Phelps and Pollak (1968) introduced. Period 1 utility is normalized to zero. Period 2 utility is $u(y)$ and period 3 utility is $v(h)$. Both functions are concave. The agent discounts future utility by the factor β, no matter how remote this future is. At date 1, the discounted lifetime utility is $\beta\left[u(y) + v(h)\right]$, but at date 2, this utility is $u(y)+\beta v(h)$. The lifetime utility of adopting technology α therefore is

$$U^1(\alpha, x) \equiv \beta\left[u(\alpha x) + v\left(1 - x\right)\right]$$

If $\beta < 1$, the mere passage of time changes how the agent ranks various (y, h) bundles, and this induces a conflict between the present (ex-ante) and future (ex-post) self. If $\beta = 1$, no conflict arises because preferences are time-consistent. The marginal rate of substitution between y and h is

$$MRS_{ex-ante} = \frac{u'(y)}{v'(h)} < \frac{u'(y)}{\beta v'(h)} = MRS_{ex-post},$$

which means that the *ex-post* indifference curves in $(y,\, h)$ space are steeper than the *ex-ante* indifference curves. These indifference curves are drawn in Figure 1. For a

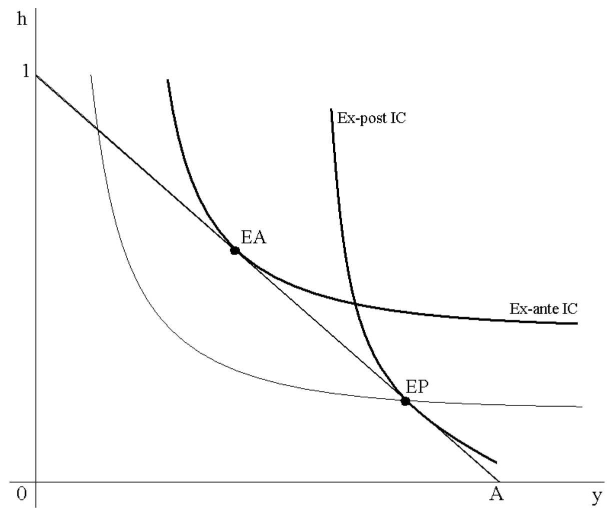

Figure 1: Ex-ante and ex-post utility maximization, fixed A

fixed technology A, the figure shows the production possibility set and two types of optima. If the agent can commit to a certain value of x, she will choose to be at the point EA which involves the use of the frontier technology. The point EA is optimal from the standpoint of *ex-ante* preferences. In contrast, the point EP is optimal with respect to the agent's preferences *at the time* she chooses x. This solution is obtained if the agent cannot commit to a particular value of x at date 1. Since the point EP lies on a lower *ex-ante* indifference curve than the point EA, the difference in welfare between these two curves is the value of being able to commit to a decision on x holding the technology fixed at A.

Choice of x: The technology, however, is not fixed, but is chosen at date 1. We shall analyze the decision problem "backwards." First, we shall describe how, at date 2, the agent chooses x, taking as given the technology level α that was already picked at date 1. After that, we shall analyze the choice of α. The agent cannot commit, at date 1, to a value of x that would maximize $U^1(\alpha, x)$. Instead, she chooses x at date 2, when her lifetime utility is no longer $U^1(\alpha, x)$, but

$$U^2(\alpha, x) = u(y) + \beta v(h).$$

She therefore chooses x to equal

$$x(\alpha) = \arg\max_x \{u(\alpha x) + \beta v(1 - x)\}.$$

Choice of α: Let $U(\alpha) = U^1(\alpha, x(\alpha))$ be the (reduced form) utility as of date 1 of adopting technology α and choosing $x(\alpha)$ optimally at date 2. The agent chooses α to maximize $U(\alpha) = U^1(\alpha, x(\alpha))$.

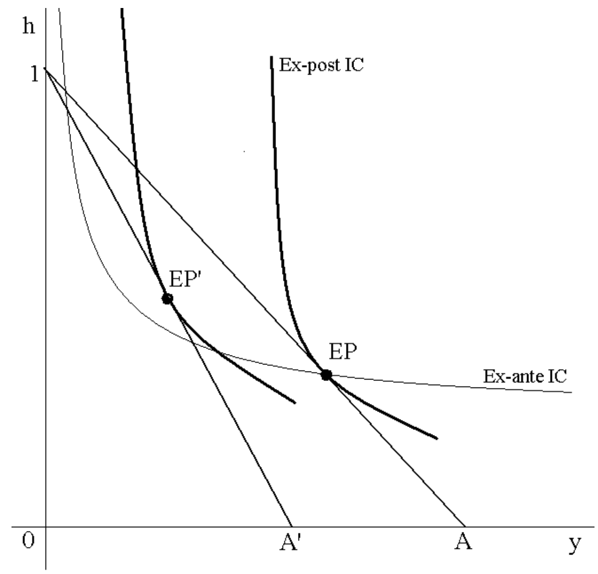

Figure 2: Ex-ante utility is higher under inferior technology $A' < A$

Figure 2 shows how the use of an inferior technology $A' < A$, may raise *ex-ante* utility. *Ex-post* utility is now maximized at the point EP', and *ex-ante* utility is higher at that point than at the point EP. When, precisely, will such a reduction in technology raise *ex-ante* utility? The first-order condition for it to be at a maximum is:

$$\frac{dU}{d\alpha} = \beta \left[xu' + (\alpha u' - v') \frac{dx}{d\alpha} \right] = 0.$$

The necessary condition that $x(\alpha)$ satisfies is

$$\alpha u' - \beta v' = 0. \tag{1}$$

The second order condition $D \equiv \alpha^2 u'' + \beta v'' < 0$ is met since u and v are concave. Taking total derivatives in (1),

$$\frac{dx}{d\alpha} = -\frac{u' + x\alpha u''}{D}.$$

$>$From (1), $u' = \beta v'/\alpha$, so that

$$\frac{dU}{d\alpha} = \beta v' \left(\beta \frac{x}{\alpha} - (1 - \beta) \frac{dx}{d\alpha} \right)$$

Since α is the return per unit of time devoted to the market, it is the analog of the wage. Therefore, we have proved the following result involving β and the wage-elasticity of labor supply, $\frac{\alpha}{x}\frac{dx}{d\alpha}$, which we denote by ε:

Proposition 1 *If*

$$\varepsilon > \frac{\beta}{1-\beta}, \tag{2}$$

then

$$\frac{dU}{d\alpha} < 0.$$

For her to prefer a lower α, the agent's preferences must be time-inconsistent with $\beta < 1$. But this is not enough; her labor supply must also be relatively elastic. The parameter ε is the *uncompensated* wage-elasticity of labor supply which depends inversely on the curvature of the indifference curves in (y, h) space. Of course, the response of labor supply to the wage varies by group. Because the "home good", h, is central to the argument, the relevant decision unit here is, presumably, the family or, perhaps, women. One would expect labor supply to market activity to be more elastic where labor-force participation rates are low, and female labor supply is, indeed, relatively elastic in developing countries – Rosensweig (1980) estimates that the uncompensated wage-elasticity for Indian women ranges from 0.67 to 2.0. Now Laibson (1996), who uses the same preference structure that we do in order to explain why people seem to favor savings plans that penalize subsequent withdrawals, argues that a value of $\beta = 0.6$ is needed to fit the data. If this value of β is reasonable, Rosensweig's higher-end estimates of ε, namely those between 1.5 and 2, meet condition (2). To see this more clearly, consider an example.

Example: $u(y) = y^{1-\theta}$, and $v(h) = h^{1-\theta}$, where

$$0 < \theta < 1. \tag{3}$$

$>$From (1), labor supply to the goods market is

$$x(\alpha) = \frac{1}{1 + \alpha^{1-\frac{1}{\theta}}\beta^{\frac{1}{\theta}}},$$

which rises monotonically from zero to one as α increases. Differentiating, we find that the labor supply elasticity is

$$\varepsilon = \frac{1-\theta}{\theta}\left(1 - x(\alpha)\right),$$

and it is decreasing in α. When $\alpha = 0$, $x = 0$, and $\varepsilon = \frac{1-\theta}{\theta}$, and, so, by Proposition 1, we find that $U(\alpha)$ *has a decreasing portion in the neighborhood of* $\alpha = 0$ if and only if

$$\theta + \beta < 1. \tag{4}$$

This condition carries over to a broader class of preferences. It is not much harder to also show that if $v(h) = h^{1-\sigma}$ and

$$0 < \sigma < 1 \tag{5}$$

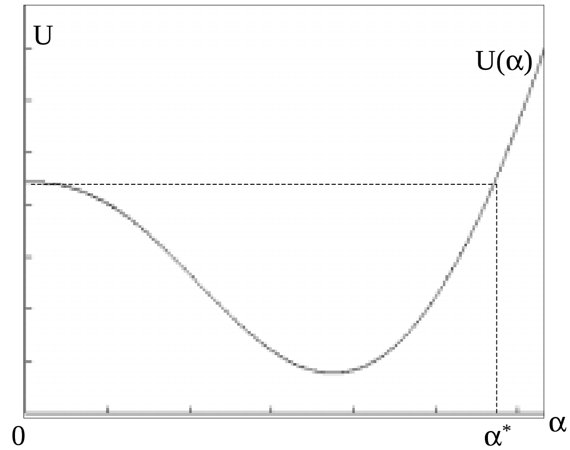

Figure 3: Value of technology: reduced form ex-ante utility

$U(\alpha)$ still has a unique minimum at a strictly positive value of α if and only if (4) holds. In this case, too, $U(\alpha)$ is U-shaped as in Figure 3.

Suppose that feasible technologies lie in the interval $[0, A]$. Then, the optimal technology choice will be either at $\alpha = 0$, or at $\alpha = A$. Which choice is better? Let $\alpha^* > 0$ be the smallest positive number such that $U(\alpha^*) \geq U(0)$. It is shown in Figure 3. If $A < \alpha^*$, the agent would reject the frontier technology, and opt for $\alpha = 0$. But if $A > \alpha^*$, the agent would choose the frontier technology A. Therefore, this is a theory of "miracles". When the frontier, A, is close enough to the point α^*, a small advance in A will induce a miracle – a large jump in the level of adopted technology and output.

3 Equilibrium with many agents

We have shown that if she cannot commit to a level of x, an isolated agent can raise her lifetime utility by exercising her option of "free disposal" of technology. In a group setting, however, the agent will have less control over her market wages because these wages depend not only on the technology that she has chosen, but on the choices that the rest of society has made as well. A single agent may therefore reject the option of high earnings and thereby ensure that she ends up with more of the home good. But what if she can buy the home good or rent home-care services? If available, this option would raise the appeal of earning a large market income and then using a part of it to *buy* the home good. In other words, the opening a market for the home good should induce technological progress in the market sector.

Let us now develop this point formally. Let there be many agents in a three-period economy. Suppose that all agents choose $\alpha = 0$ in period one. Each of them then sets ex-post labor supply $x = 0$, consumes 1 unit of the home good and zero units of the market good, and thereby enjoys a lifetime utility of $U(0) = \beta[u(0) + v(1)]$. In this situation, the last unit of home time produces a utility level $\beta v'(1)$. If ex-post an agent were offered wage w to supply her time on the home-good market, she would do so if

$$w \geq \frac{\beta v'(1)}{u'(0)}.$$

The right-hand side of this inequality is the supply price of home-good labor in an economy where no one is able to produce the market good, and this supply price tends to zero as $u'(0)$ becomes large relative to $v'(1)$. Then any agent who at date 1 deviates to adopting a frontier technology will have a chance to hire everybody else in the economy to produce the home good for her for close to a zero wage. Clearly, such an agent can attain a higher utility than $U(0)$, making the deviation profitable. Thus we have proved the following result:

Proposition 2 *If $u'(0) = +\infty$, then in a group setting, some agents always choose $\alpha = A$.*

Proposition 2 says that if $u'(0)$ is large enough, there is no equilibrium where everyone rejects technology. The mechanism that drives these results is the same as before - the inability to commit to a limited level of market participation. Choosing $\alpha = 0$ no longer removes the temptation to work outside the home, as a home-good market forms in the second period. We have shown that when $A \in [0, \alpha^*]$, the isolated agent invariably chooses $\alpha = 0$. But, by Proposition 2, a group of agents will always contain some members that choose $\alpha = A$. In this sense, groups of agents should be technologically more progressive than isolated individuals.

The question remains whether the introduction of a market for the home good will entirely eliminate the incentive to reject technology. To answer this question we need to specify how an economy with a home-good market would work.

3.1 The market for h

Labor demands and supplies are set in period 2 and they, therefore, must maximize *ex-post* utility taking market prices and the period 1 technological choices as given. Suppose that an agent has adopted market technology α ex-ante and ex-post is faced with the choice of market activity. As before, let x be the time that a household uses to operate the market technology α, and z be time that a household supplies to the home-care market. The household can also buy time, τ, in the market for home-care, at a price of w per unit. The utility of the market good is $u(y)$, and the utility of the home good is $v(h)$. The effective time input into the production of the home good, h, given by

$$h = 1 - x - z + \gamma\tau,$$

where $0 < \gamma < 1$.

The case $\gamma = 0$ corresponds to autarchy, where only the agent herself can produce the home good, and in this case there can be no trade among agents. In the case $\gamma = 1$, the model cannot determine how much of the home good changes hands on the market and how much is produced "in house". Everyone who produced final output would do so using the frontier technology. In order to produce a determinate outcome in which the home-good market is open *and* in which some people choose the primitive technology, we shall have to assume that γ is positive but strictly less than 1. This assumption implies that hired help is an inferior, though not entirely useless substitute for one's own time in producing the home good. This makes sense if, for example, the home good is connected to the rearing of young children.

The wage, w, is exogenously given to the household and the technology, α, is predetermined. A household's *ex-post* decision rules, $x^d(\alpha, w), z^d(\alpha, w)$, and $\tau^d(\alpha, w)$, solve the problem

$$\max_{x,z,\tau} \{u[\alpha x + w(z - \tau)] + \beta v(1 - x - z + \gamma\tau)\}. \tag{6}$$

If we substitute these decision rules into the ex-ante utility function, we obtain the reduced form ex-ante utility:

$$V(\alpha, w) = \beta\left\{u\left[\alpha x^d + w\left(z^d - \tau^d\right)\right] + v\left(1 - x^d - z^d + \gamma\tau^d\right)\right\}. \tag{7}$$

3.2 Definition of equilibrium

Equilibrium is a wage w, and a distribution the agents' technology choices over $[0, A]$. Agents must be indifferent between the technologies that are chosen in equilibrium. For now we shall assume – and later on we shall prove – that any equilibrium can involve at most two types of agents: those that choose $\alpha = 0$ and supply home-care services, and those that choose the frontier technology $\alpha = A$ and demand home care. In any equilibrium with home care both choices yield the same utility:

$$V(0, w) = V(A, w) \tag{8}$$

Households will be either suppliers or demanders of home-care time, not both. The high-α households will buy home-care time from the low-α households, unless we are in a degenerate equilibrium in which the market is inactive. The first order conditions for the two types of households then simplify.

Anyone who chooses $\alpha = 0$ will have to be a supplier of the home good in order to be able to consume any y at all. Her consumption of goods is wz, and her labor supply at wage w is $z(0, w)$:

$$z(0, w) = \arg\max_{z}[u(wz) + \beta v(1 - z)]. \tag{9}$$

A high type has $\alpha = A$, $x = 1$, and $z = 0$.[2] Her consumption of goods is $A - w\tau$. Her demand for home-care labor $\tau(A, w)$ maximizes the ex-post utility. Decision variable, τ, will be in the interior iff $w \leq \gamma A$. The first-order condition of the $\alpha = A$ agent reads

$$\tau(A, w) = \arg\max_{\tau} \left[u\left(A - w\tau\right) + \beta v\left(\gamma\tau\right)\right] \tag{10}$$

Let π denote the fraction of people that choose $\alpha = A$, in which case the fraction $1 - \pi$ choose $\alpha = 0$. In this case, the market for home-care labor clears if

$$\tau(A, w) = \frac{1 - \pi}{\pi} z(0, w) \tag{11}$$

Definition: *Equilibrium consists of four scalars, w, z, τ and π that satisfy (8), (9), (10), (11) and where $V(\alpha, w)$ is defined by (7).*

For some values of A the equilibrium with positive τ, z and w may not exist - the home-care market may be closed. We then have a symmetric equilibrium with $\pi = 1$.

3.3 Properties of the equilibrium

When $U(\alpha)$ has a U-shape, the home-care market arises for sufficiently low A. We will continue to use the assumptions made in Proposition 1 guaranteeing that $U(\alpha)$ will initially be decreasing and will have a unique minimum.

Because $U(\alpha)$ is non-monotonic, we cannot a-priori rule out equilibria with technology choice below the frontier: $0 < \alpha < A$. A fraction of agents may have an incentive to adopt technology α below the frontier when next period they expect a home-care market with wage w. The following proposition, proved in the appendix, shows values of α for which the home-care market can arise:

Proposition 3 *Let β, u and v satisfy (4), (3), (5) and let $\gamma \in (0, 1)$. Then there is a unique number $\hat{\alpha} > 0$ that solves the equation*

$$U(\gamma\hat{\alpha}) = U(\hat{\alpha}) \tag{12}$$

such that

(i) *For $\alpha \leq \hat{\alpha}$, an equilibrium with $w_\alpha, \tau_\alpha > 0$, and $0 < \pi(\alpha) < 1$ exists,*

and

(ii) *For any $\alpha > \hat{\alpha}$, no equilibrium in which $\pi(\alpha) < 1$ exists.*

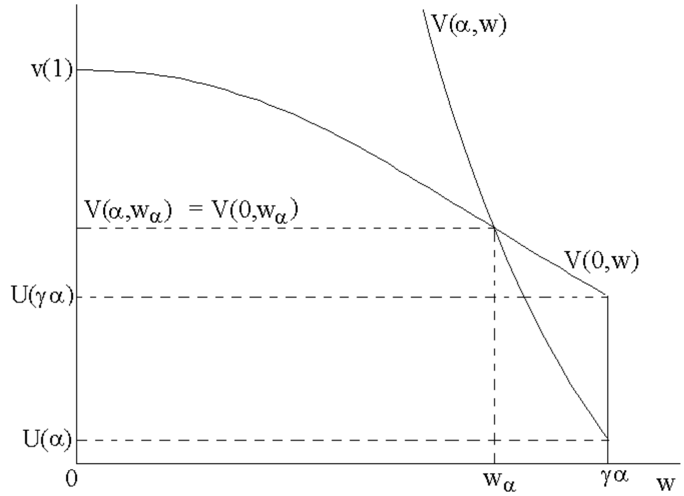

Figure 4: Home care market equilibrium

Figure 4 shows how the wage w_α is determined on the home-care market. For a given α, the equilibrium wage cannot exceed $\gamma\alpha$, or else demand for home care is zero. The figure plots $V(0,w)$ and $V(\alpha,w)$ – the supply-side and demand-side ex-ante utilities – on w. At equilibrium, the two must be equal. As α rises, the $V(\alpha,w)$ curve shifts up and to the right, while the $V(0,w)$ curve stays put. The intersection of the two curves thus moves farther and farther to the right, getting closer and closer to the maximum wage $\gamma\alpha$. Finally, when $\alpha = \hat{\alpha}$, the two curves cross at the maximum wage, and when $\alpha > \hat{\alpha}$ they never cross on the interval $[0, \gamma\alpha]$. For sufficiently high α the home-care market closes, because for any feasible wage no agent has an incentive to enter the home care sector:

$$V(0,w) < V(\alpha,w),\ w \in [0,\gamma\alpha],\ \alpha > \hat{\alpha}.$$

Therefore, condition (8) cannot hold when $\alpha > \hat{\alpha}$.

The home care market breaks down because the opportunity cost of supplying home care grows with α. Thus the reservation wage of the home care provider grows with α and eventually prices her out of the market next period. Then, no one supplies home care, and no one expects to hire outsiders to produce the home good.

Note that because $\gamma < 1$ it is necessarily the case that $\hat{\alpha} < \alpha^*$. It is left to characterize the equilibrium for $\alpha \in [\hat{\alpha}, \alpha^*]$. By Proposition 3 we know that this cannot be an asymmetric equilibrium, and by Proposition 2 this cannot be a symmetric equilibrium with $\alpha = 0$. It turns out that when $A \in [\hat{\alpha}, \alpha^*]$, every agent will choose frontier technology, the same symmetric equilibrium as in the case $A > \alpha^*$.

[2] This is the case whenever $\tau > 0$. Demand for home care is positive whenever $w \leq \gamma A$, which makes it optimal to spend all the time producing ($x = 1$) and not supplying any home care ($z = 0$).

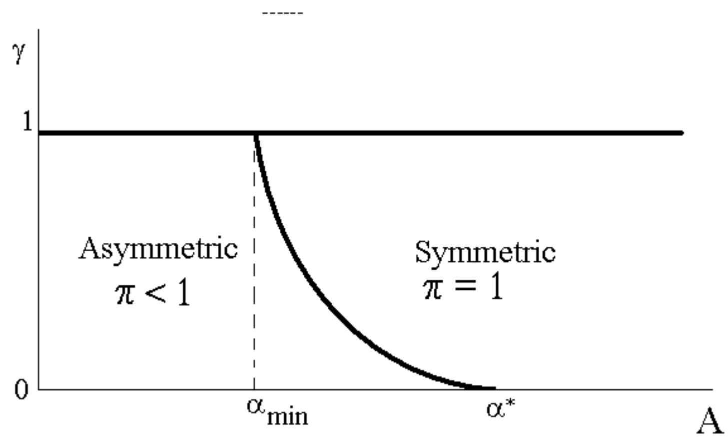

Figure 5: Type of equilibria depending on A and γ.

The following proposition, also proved in the Appendix, shows this result as well as our earlier conjecture that an asymmetric equilibrium must involve exactly two technology choices: $\alpha = 0$ and $\alpha = A$.

Proposition 4 *The following equilibria arise depending on A:*

Values of A	Type of Equilibrium
$A \leq \hat{\alpha}$	A fraction of agents operates frontier technology $\alpha = A$, $0 < \pi(\alpha) < 1$
$A > \hat{\alpha}$	Everyone operates the frontier technology $\alpha = A$, $\pi(\alpha) = 1$

When $A > \hat{\alpha}$, the home care market breaks down, as explained above. For $A > \hat{\alpha}$, the equilibrium is for all the agents to operate frontier technology. This result may seem surprising , because when $A \in [\hat{\alpha}, \alpha^*]$, $U(0) > U(A)$, so any agent could collect a higher ex-ante utility if she simply stayed at home. However, the agent *cannot commit* not to work ex-post. Then, having chosen $\alpha = 0$, she will necessarily offer herself at the home care market ex-post, which will yield her ex-ante utility below $U(A)$. Knowing that she cannot commit to staying at home, the agent chooses $\alpha = A$ as the next best alternative.

In section 2, we had found that the isolated agent never rejects the frontier technology as long as $U(A)$ is everywhere increasing in A. This still holds in a group setting because everyone must have the same lifetime utility – the lifetime utility of someone who chooses $\alpha = 0$ is at most $U(\gamma A)$, but if $U(A)$ is strictly increasing, the people that choose $\alpha = A$ would be strictly better off, and in equilibrium, $\pi = 1$.

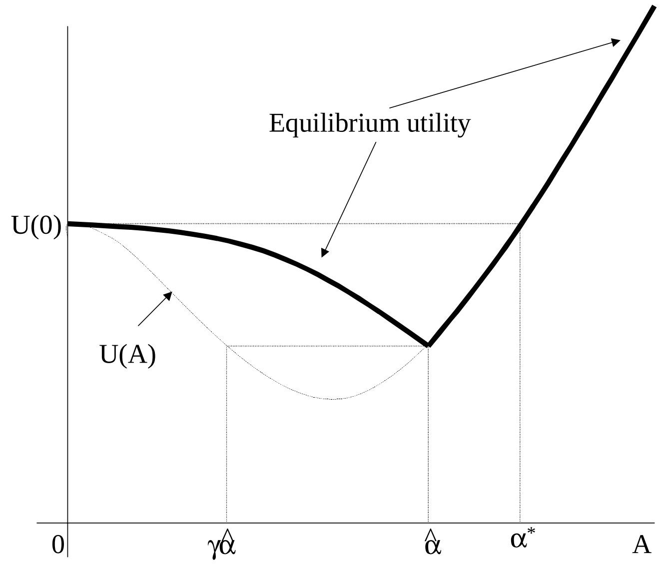

Figure 6: Equilibrium utility

Figure 5 summarizes the types of equilibria for different values of A and γ. The curve on the plot shows the locus of the points $\alpha = \hat{\alpha}(\gamma)$ for $\gamma \in (0, 1)$. It follows from condition (12) that $\lim_{\gamma \to 0} \hat{\alpha}(\gamma) = \alpha^*$ and $\lim_{\gamma \to 1} \hat{\alpha}(\gamma) = \alpha_{\min} = \arg\min_\alpha U(\alpha)$. For any $\gamma \in (0, 1)$ there is an asymmetric equilibrium for $A \leq \hat{\alpha}(\gamma)$, and there is a symmetric equilibrium for $A > \hat{\alpha}(\gamma)$.

3.4 Development and welfare

An open home-care market makes people better off *ex-post*, but worse off *ex-ante* because they cannot restrain themselves from working and are thus unable to collect the autarchy *ex-ante* utility $\max\{U(0), U(A)\}$. The bold line on Figure 6 shows the equilibrium utility: when $A \leq \alpha^*$, the agents collect lower utility than in autarchy. The figure shows that asymmetric equilibrium utility decreases in A. This is because wages in the home care sector grow with A, pushing the agent even further away from home work. This reduces ex-ante utility of the home care provider. The equilibrium utility of the market producer is, of course, identically equal to that of the home care provider. The symmetric equilibrium utility is still below the autarchy utility when $A \in [\hat{\alpha}, \alpha^*]$, because no agent can commit to staying at home when he can be hired as home help ex-post. Finally, when $A > \alpha^*$, the symmetric equilibrium utility is at its autarchy level $U(A)$.

Since market output rises with A, the figure implies that a society with a lower per capita GDP does not necessarily do worse in terms of lifetime utility. In line with this, Nicholas and Steckel (1991) find that health declined in England in the decades surrounding 1800, and Costa and Steckel (1995) find that the substantial increase in US incomes between 1830 and 1870 was insufficient to offset the utility loss stemming from a general decline in health that Americans experienced during that era.

Our theory predicts not only that utility should initially fall with development, but also that equilibrium consumption of the home good should be higher for agents who choose an inferior technology. This is supported by Costa and Steckel (1995, fig. 3) evidence suggesting that farmers stayed the healthiest of all occupational categories. Farmers born in 1820-40 were significantly taller than laborers, artisans or professionals. Apparently, staying on the farm meant access to better food which was beneficial for farmers' and their children's health.

3.5 Development and the ability to commit

Even for an isolated agent, the inability to commit on x leads to a loss of utility. When a group of agents acts in a decentralized way, they will suffer an even bigger utility loss, because the situation in which they all choose $\alpha = 0$ is not an equilibrium. An example of how market participation erodes a low-technology commitment is the history of William Penn's Quaker colony which experienced a transition from simple piety to mainstream consumerism because its members were drawn to commerce. Initially, the Quakers used wage and price controls as commitment devices. When other settlers moved to Pennsylvania, trading made young Quakers affluent and quickly overwhelmed their commitment to simplicity (Shi, 1985). Our model predicts that even though their transition to higher wages and modern methods would have occurred eventually anyway, the Quakers' inability to remain isolated hastened the transition.

In contrast, the ability of the Amish society to maintain its religion and life-style may be due to their isolation. Cosgel (1993) notes that Amish farmers manage to keep a distance from the outside world by producing more variety than other farmers and relying only on labor within their religious network. This fits our model's implication that an effective commitment to an inferior technology requires that one cannot take part in market exchange. The Amish implemented this commitment by rejecting the tractor and other mechanized farming machinery.

Therefore, society may wish it could shut out all technologies in the interval $[0, \alpha^*]$. But it would be even better if it could place an upper bound on x, thereby allowing each agent to choose frontier technology and not have to worry about subsequently yielding to the temptation to work hard. According to our model, a society will seek ways to limit its citizens' market work and that when it has found a way do so, a period of rapid technological growth should follow. The following are examples in which societies have managed to limit what we call x:

(a) *Early retirement inducements*: A working senior citizen foregoes his social security income, and this is an implicit tax on work. Early retirement legislation has brought forward the age at which this implicit tax becomes effective. The US and

European countries alike have put in place a barrage of incentives to retire early. Such indirect inducements are socially quite costly, however, because they raise the tax-burden for the working population, and their aim is probably redistributive.

(b) *Child labor laws* place a limit on lifetime market work. Acemoglu and Angrist (2000) find that states with child labor laws in place returns to schooling were higher. They have their own interpretation of what this correlation means. We interpret it as saying that when you can place an upper bound on your market work x, you will choose frontier technology, and your market income will be higher.

(c) *Direct restrictions on hours worked*. Such restrictions should limit *hours per person*, and not employment. Examples of legal limits on weekly hours worked are the 1938 Fair Labor Standards Act in the US, and recent legislation in France (but these seemed to have been driven by a desire to reduce unemployment by spreading the available work among a larger group of people, and can no more be explained by our model than can the rioting of the Luddites). Some social norms have discouraged excessive work effort. For instance, in Christianity (Sunday) and Judaism (the Sabbath) a day is set aside for rest.

When a society cannot manage to put a limit on x, it can, as a second-best policy, still make its citizens better off by shutting out foreign technology while $A < \alpha^*$. This follows from Figure 6. Under such a policy domestic output will be low and then rise dramatically when the restriction is removed. As an example, consider Japan whose self-imposed isolation lasted from 1640s till 1860s. The transition to free trade that started in 1858 was accompanied by a 65% rise in real income, due mainly to a big rise in the prices of exportables (Huber 1971). In our model such price rises would affect work incentives in exactly the same way as would a better technology.

The Costa-Steckel evidence suggests that by shutting out foreign technology, the US. could have raised the welfare of the generations alive in the 1830 - 1870 period. Fortunately for the generations of Americans that came later, such protectionism never happened. But medieval China, like Japan, did adopt a closed door policy in the 15th century when the emperor imposed an effective ban on ocean shipping. Edwards (1999) documents that market activity in China then had to face high taxes and the same is true in India today. Curiously, ancient Chinese and Indian philosophies argue that material progress cannot make us happy, and that what should matter to us is h and not y.

We do not explain, however, why such laws and norms emerge in some societies but not others. Our model can accommodate only the crudest possible variation in the ability to commit. In a model where technology is exogenous but that is richer than ours in other respects, Barro (1997) presents a sophisticated analysis of the effects on savings and growth of variations in the ability to commit to future consumption.

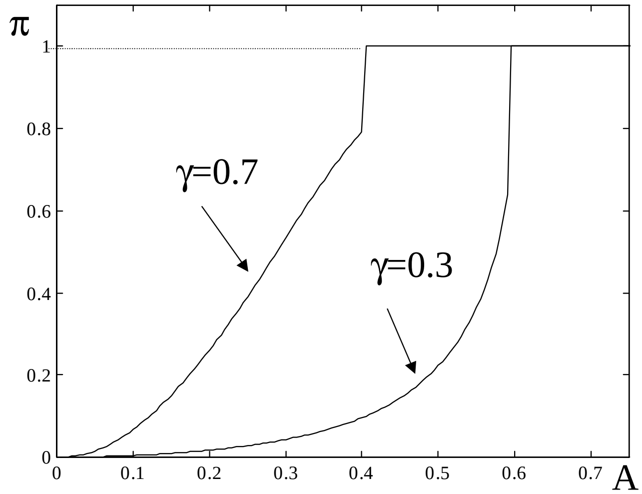

Figure 7: Development paths $\pi(A)$ for diffeent values of γ.

3.6 Development and income inequality

In the model, a gradual rise in A induces three stages of development. While A is small, most people are in the traditional sector. Next, as A rises, people start to enter the market sector, and income inequality appears between those who work in the modern sector, and those who remain in the traditional sector. During this phase, output grows, but utility falls. While A is rising in this phase, more and more people adopt the frontier technology. Finally, A reaches the point at which everyone that has not yet done so enters the market sector "en masse", and the society then catches up with the development leaders and thereafter keeps pace with them.

We can plot the equilibrium fraction of agents that go to the market π as a function of the position of the frontier technology A. This may be thought of as the "development path" for the society with the exogenously growing technological frontier. Figure 7 shows two $\pi(A)$ plots for different values of γ. A country where home production technology is more flexible (where outsiders are better substitutes in home production) will have a higher value of γ.The graph shows that countries with more flexible home production (higher γ) will grow faster and will have higher market output $y(A) = A\pi(A)$. Since $\frac{\partial \hat{\alpha}}{\partial \gamma} < 0$, miracles will also occur earlier in countries with higher γ. The graph also shows that "miracles"[3] are less pronounced in countries with high values of γ. While only a fraction of the population operates the market technology and $w < A$, there is inequality in earned income between the home-care

[3] A miracle occurs when there is a jump in market participation at $A = \hat{\alpha}$. Therefore, the "size" of the miracle is proportional to $\pi(\hat{\alpha} + 0) - \pi(\hat{\alpha} - 0) = 1 - \pi(\hat{\alpha} - 0)$.

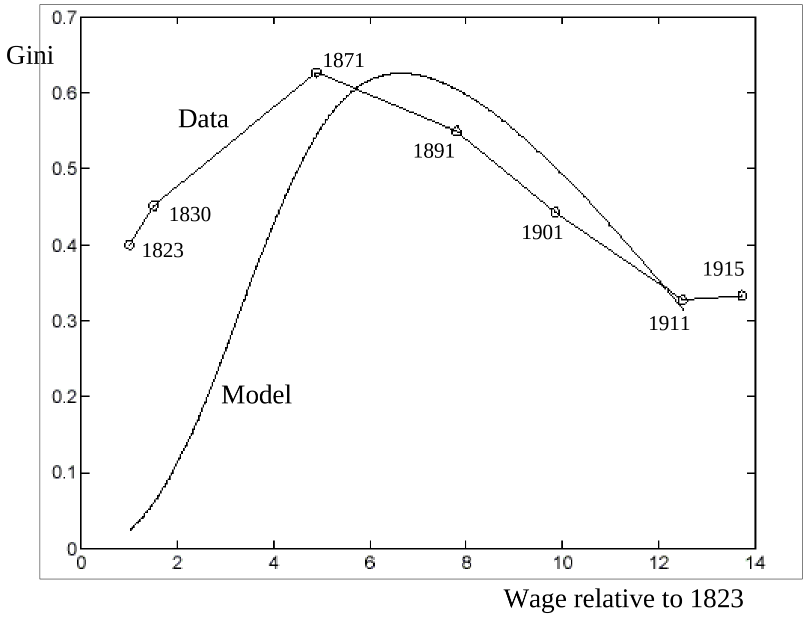

Figure 8: Simulated and actual Kuznets curves for Britain, 1823-1915

providers and producers. The former have less wage income, but produce more home good. The wage income disparity follows a Kuznets-type relationship as A grows. The income inequality first increases, because there is entry in high-wage market sector. While $\pi(A)$ is sufficiently small, the wage in the home care sector grows slower than A. However, as A increases, demand for home care grows, which commands a higher wage. At some point the wage at the home-care market starts growing faster than A, which makes income distribution increasingly more equal. Inequality disappears permanently at the point where $A = \hat{\alpha}$.

Figure 8 depicts the time path of the Gini coefficient that the model predicts and the actual historical series of the Gini in Britain reported in Williamson (1985)[4]. The vertical axis measures the values of the Gini coefficient at various dates. On the horizontal axis, however, instead of calendar time, we plot the average real wage[5] for 1823-1915. The plot is scaled so that the British. real wage in 1823 is 1. For our model, the implied average wage is

$$\bar{w}_t = \pi\left(A_t\right) A_t + \left[1 - \pi\left(A_t\right)\right] w_t.$$

Because we do not know the mapping from calendar time to $A\left(t\right)$, we scale our Kuznets curve so that it flattens out (becomes zero) at the same wage as the historical

[4] The Gini coefficient for 1823-1915 is estimated from tax data and reported in Table 4.2, p. 61.

[5] ibid, Appendix Table C.1

series do, and also starts at the wage equal to 1. This determines the initial and the final values of A for the simulation. We leave $\theta = 0.3$ and $\beta = 0.6$ at their benchmark values and choose the value of $\gamma = 0.39$ to match the peak Gini coefficient of 0.62.

4 Conclusion

Laibson and Barro have stressed how when we cannot commit to future consumption our savings and income growth decline. We have added the insight that when we cannot commit to future consumption of the home good, we may choose a low-paying occupation as a second-best form of commitment. We have characterized the preferences that make such behavior likely, in terms of the time-inconsistency parameter and in terms of the elasticity of supply of labor. We have also found some interesting consequences for the relation between development and inequality and for development miracles.

The gap between the rich and poor is so wide, and our explanation of it so narrow, that new explanations should be welcome. How much poverty stems from the force we have stressed? We do not know. But the "list of suspects" now has a new member.

References

[1] Acemoglu, Daron, and Joshua Angrist. "How Large are the Social Returns to Education? Evidence from Compulsory Schooling Laws." NBER WP 7444, January, 2000.

[2] Barro, Robert "Myopia and Inconsistency in the Neoclassical Growth Model." NBER WP 6317, December 1997.

[3] Carillo, Juan, and Thomas Mariotti. "Strategic Ignorance as a Self-Disciplining Device." *Review of Economic Studies*, forthcoming.

[4] Cosgel, Metin M. "Religious Culture and Economic Performance: Agricultural Productivity of the Amish,1850-80", *Journal of Economic History* 53, no. 2 (June 1993): 319 - 331.

[5] Costa, Dora and Richard Steckel. "Long-Term Trends in Health, Welfare, and Economic Growth In the United States." NBER WP Ser. on Historical Factors in Long Run Growth 76, November 1995.

[6] Edwards, Alan , "Essays in Fiscal Centralization and Economic Development", Ph. D. thesis, University of Minnesota, August 1999.

[7] Huber, J. Richard. "Effect on Prices of Japan's Entry into World Commerce after 1858", *The Journal of Political Economy*, Vol. 79, No. 3. (May - Jun., 1971), pp. 614-628.

[8] Krusell, Per, and Jose-Victor Rios-Rull. "Vested Interests in a Positive Theory of Stagnation and Growth." *Review of Economic Studies* 63 (1996): 301 - 329.

[9] Laibson, David. "Hyperbolic Discount Functions, Undersaving, and Savings Policy." NBER WP 5635, June 1996.

[10] Nicholas, Stephen, and Richard Steckel. "Heights and Living Standards of English Workers during the Early Years of Industrialization, 1770-1815*." Journal of Economic History* 51, no. 4 (December 1991): 937 - 57

[11] Parente, Stephen, and Edward Prescott. "Monopoly Rights: A Barrier to Riches." Staff Report 236, FRB Minneapolis, July 1997

[12] Parente, Stephen, Richard Rogerson, and Randall Wright. "Homework in Development Economics." University of Pennsylvania, 1999.

[13] Phelps, Edmund, and Robert Pollak. "On Second-Best National Saving and Game-Equilibrium Growth." *Review of Economic Studies* 35, no. 2 (April 1968): 185 - 199..

[14] Mark Rosenzweig. "Neoclassical Theory and the Optimizing Peasant: An Econometric Analysis of Market Family Labor Supply in a Developing Country." *Quarterly Journal of Economics* 94, No. 1. (February 1980): 31 - 55.

[15] Shi, David E. *The Simple Life: Plain Living and High Thinking in American Culture.* New York: Oxford University Press, 1985.

[16] Strotz, Robert. "Myopia and Inconsistency in Dynamic Models of Utility Maximization." *Review of Economic Studies* 23, no. 3 (1955-56): 165 - 180.

[17] Ueda, Kenichi. " Industrialization and Individualism." University of Chicago, 1999.

[18] Williamson, Jeffrey G. "Did British Capitalism Breed Inequality?", George Allen & Unwin, 1985.

[19] Zeira, Joseph. "Workers, Machines, and Economic Growth." *Quarterly Journal of Economics* 113, no. 4 (November 1998): 1091 - 1117.

5 Appendix

Proof of Proposition 3: The demand for home care services $\tau(\alpha, w)$ is implicitly defined by the first order condition

$$wu'(\alpha - \tau(\alpha, w)w) - \beta\gamma v'(\gamma\tau(\alpha, w)) = 0$$

where $w \leq \gamma\alpha$, and $\tau(\alpha, w) = 0$ for all $w > \gamma\alpha$.

Ex-ante utility of a person who hires a home care supplier is monotonically decreasing in w :

$$\frac{dV(\alpha, w)}{dw} = \frac{d}{dw}\left(u(\alpha - \tau(\alpha, w)w) + v(\gamma\tau(\alpha, w))\right) = u'(c)\left(-w\frac{\partial\tau}{\partial w} - \tau\right) + \gamma v'(h)\frac{\partial\tau}{\partial w} =$$

$$= -u'(c)\tau + wu'(c)\frac{\partial\tau}{\partial w}\left(\frac{1}{\beta} - 1\right) < 0,$$

since

$$\frac{\partial\tau}{\partial w} = \frac{u'(c) - w\tau u''(c)}{w^2 u''(c) + \beta\gamma^2 v''(h)} < 0$$

Ex-ante utility of the home care supplier is monotonically decreasing as well, since

$$V(0, 0) = u(wz(0, w)) + v(1 - z(0, w)) \equiv U(w),$$

and $U(w)$ must be monotonically decreasing for $w \leq \gamma\hat{\alpha}$ (The point $\gamma\hat{\alpha}$ must be located on the decreasing portion of U because otherwise $\hat{\alpha}$ cannot solve (12)).

At wage $w = 0$ the utility of the person who hires a home care supplier is infinite (because $\tau(\alpha, 0) \to \infty$) but utility of the home care supplier is finite and equals $v(1)$ (because $z(0, 0) = 0$). At the maximum wage $w = \gamma\alpha$, the home care supplier gets $V(\gamma\alpha, 0) = U(\gamma\alpha)$ while the person who hires a home care supplier gets $V(\alpha, \gamma\alpha) = U(\alpha)$ (this person is indifferent between hiring at wage $\gamma\alpha$ and not hiring a home care supplier). Since $U(\cdot)$ must be strictly decreasing for $\alpha \leq \gamma\hat{\alpha}$ and strictly increasing for $\alpha > \hat{\alpha}$

$$V(\alpha, \gamma\alpha) = U(\alpha) < (\leq) U(\gamma\alpha) = V(0, \gamma\alpha),\ \alpha < (\leq)\hat{\alpha}$$

When $\alpha > \hat{\alpha}$ and $w \leq \gamma\alpha$ this inequality reverses the sign, because

$$V(\alpha, w) \geq V(\alpha, \gamma\alpha) = U(\alpha)$$

(for any wage where $\tau \neq 0$), and

$$U(\alpha) > U(w) \equiv V(0, w)$$

since $U'(\alpha) > 0$ for any $\alpha > \hat{\alpha}$. Therefore,

$$V(\alpha, w) > V(0, w) \text{ for any } \alpha > \hat{\alpha} \text{ and } w \leq \gamma\alpha.$$

The home care equilibrium does not exist for $\alpha > \hat{\alpha}$. ■

Proof of Proposition 4 Suppose that $\alpha \leq A \leq \hat{\alpha}$ and the home care market is open: $w > 0$. Three ex-post decisions are available to the person whose technology choice is α: (1) supply home care at wage w, (2) operate market technology α and not demand home care and (3) operate market technology α and demand home care at wage w. Using the results of Proposition 3, the ex-ante optimal technology choice can be expressed as

$$\alpha \in \arg\max_{\alpha} \left[\max\left\{U(w), U(\alpha), V(\alpha, w)\right\}\right]$$

Because

$$\frac{\partial V(\alpha, w)}{\partial \alpha} > 0$$

the person who decides to demand home care will always prefer to operate the frontier technology A. Also observe that if w is the equilibrium wage, then $U(w) > U(\alpha)$. Therefore, $\alpha = A$. is in the argmax. Supplying home care is another possibility that gives the same ex-ante utility. Therefore $\alpha = 0$. is in the argmax as well.

Now consider the case $A \in [\hat{\alpha}, \alpha^*]$ where the home care market is closed. We will prove that every agent choosing $\alpha = A$ is an equilibrium by showing that a single agent has no profitable deviation.

Firstly, observe for any $\alpha \geq \gamma A$, the deviating agent will not supply home care, because his opportunity cost of time exceeds the maximum home care wage. Therefore, he will collect utility of $U(\alpha)$. Since

$$U(\alpha) < U(A),\ \alpha \in [\gamma A, A],\ A > \hat{\alpha}$$

this does not constitute a profitable deviation

If $\alpha < \gamma A$, the ex-post optimal action for the agent will be to offer herself in the home care sector. Since there will be a single agent supplying home care and multiple agents demanding his services, the wage will be bid up to the maximum amount γA. The agent will then collect the ex-ante utility $U(\gamma A)$.Since

$$U(\gamma A) < U(A),\ A > \hat{\alpha}$$

this does not constitute a profitable deviation.

Finally, if $A > \alpha^*$,

$$U(A) > U(\alpha),\ \alpha \in [0, A)$$

so choosing $\alpha = A$ is an equilibrium. ■