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Building Blocks for Barriers to Riches*

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ABSTRACT

Total factor productivity (TFP) differs greatly across countries. In this paper, I provide a novel rationalization for these differences. I consider two environments, one in which enforcement is full and the other in which enforcement is limited. In both settings, manufactured goods can be produced using a high-TFP technology or a low-TFP technology; there is a fixed cost associated with adoption of the former. I suppose that the fixed cost is sufficiently small that adoption takes place in a symmetric Pareto optimum in the limited-enforcement setting. Under this condition, I prove two results. First, adoption takes place in all Pareto optima in the full-enforcement setting. Second, adoption may not take place in a Pareto optimum in the limited-enforcement setting, if the division of social surplus is sufficiently unequal. I conclude that limited enforcement and high inequality interact to create particularly strong *barriers to riches* (in the language of Parente and Prescott (1999, 2000).

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1. Introduction

There are enormous differences in total factor productivity (TFP) across countries. Parente and Prescott (1999, 2000) argue that these differences are substantially due to particular economic institutions in low-TFP countries. In their language, these institutions are *barriers* to the adoption of superior technologies. From the point of view of standard economic reasoning, these barriers are puzzling. Institutions are endogenous. Why would societies choose to use institutions that lead to such inefficient means of production?

In this paper, I address this question. I consider two different types of environments: one with *full enforcement* and one with *limited enforcement.* In the latter environment, agents can at any time walk away from any societal arrangement and consume their original endowments; in the former, they cannot.[1] I look at Pareto optimal allocations of resources in the two economies, and prove two results about them.

The first result is that if technology adoption occurs in a symmetric Pareto optimum in the economy with limited enforcement, it occurs in *all* Pareto optima in the economy with full enforcement. Making enforcement full can only make adoption of technology more attractive. The second result concerns the effects of inequality. In the society with limited enforcement, the adoption decision differs across Pareto optima depending on the distribution of the social surplus. In particular, if the distribution of the social surplus is extremely unequal, adoption is less likely to occur than if the distribution is egalitarian. Thus, I conclude that the key building blocks for barriers to riches are *limited enforcement* and sufficiently *high inequality.*

Limited enforcement is a simple way to model a substantive problem in actual economies.

[1] In the language of implementation theory, agents face ex-post individual rationality constraints in the environment with limited enforcement. I use the term "limited enforcement" to highlight the nature of the technological limitation in the environment.

Especially in countries with a large agrarian sector, it is relatively costly to monitor people's incomes. These costs make it difficult for governments to collect taxes from its citizens. By assuming that agents can walk away with their original endowments, I take this problem to an extreme: I am essentially assuming that income tax collection is impossible.

It is important to emphasize that despite my use of Pareto optimality, I intend these results to be positive, not normative. Some economists use the terms "good" and "Pareto optimal" equivalently. I do not. The important property of a Pareto optimal institution is that it has a special kind of robustness: any attempt to change societal institutions that lead to Pareto optimal allocations will be met with resistance by some interest group. In this sense, the barriers to adoption that I identify are especially strong.

The technical specifics are as follows. I construct an environment with two goods, cars and food. There are two possible constant marginal-cost technologies to produce cars. I term the technology with the higher marginal cost, *primitive,* and the technology with the lower marginal cost, *advanced.* There is a fixed cost associated with using the latter technology which I call the cost of adoption. Agents have identical ex-ante preferences over cars and food, but are subject to a preference shock that gives them ex-post differences in their willingness to substitute food for cars. Importantly, the realization of the preference shock is private information.

There are two versions of the environment. In the first, there is full enforcement, so that agents can commit ex-ante (pre-preference shock) to a social contract. In this economy, agents who do not buy cars may be forced to give up food to pay for technological adoption. In the second, there is only limited enforcement. Agents can walk away ex-post with their endowments of food. In this latter environment, it is impossible to tax food away from agents who do not buy cars.

I parameterize the latter environment so that it is Pareto optimal to adopt the advanced technology if the distribution of societal surplus is egalitarian. I then show that if enforcement is instead full, it is Pareto optimal to adopt the advanced technology in all Pareto optima (regardless of the distribution of societal surplus). In contrast, in the limited-enforcement environment, in a Pareto optimum with a sufficiently unequal division of surplus, adoption does not take place.

The intuition behind the results is simple. When enforcement is limited, societal surplus can only be transferred from one group of agents to another by charging the former group a high price for cars. Thus, the enforcement limits reduce the number of consumers of cars, which reduces the incentive for society to choose to adopt the advanced technology. Higher inequality increases the need to transfer societal surplus across agents. Hence, inequality and enforcement limits interact to further reduce the incentives for society to adopt the advanced technology.

Monopoly is often identified as a key force that interferes with the adoption of new technologies. I go on to look at the properties of monopoly in the limited-enforcement economy. Specifically, I assume that there is a single firm which owns the two production technologies. The shareholders of the firm make production and pricing decisions so as to maximize their utility (their preferences are identical at the time decisions are made, so a unanimity principle applies).

I show that as long as the firm is allowed to offer a price discount to its own shareholders, the monopolistic outcome is always Pareto optimal. However, the monopolistic outcome may or may not feature adoption. If all agents are shareholders in the monopoly, then adoption does take place. If only a small fraction of agents are shareholders, then adoption does not take place.

This paper is largely motivated by the recent work of Parente and Prescott (1999, 2000). Like Holmes and Schmitz (1995), they argue that particular institutions (such as protection of monopoly rights) can lead to non-adoption of superior technologies. They abstract from the question of why societies continue to use these institutions even though they are leading to huge losses in social welfare. It is this open question that I address.

The key friction in my analysis is limited enforcement. Others have shown how enforcement limitations can affect the nature of efficient production. See, for example, Mailath and Postlewaite (1990)'s work on public goods provision, Marcet and Marimon (1992)'s work on growth, and Cooley, Marimon, and Quadrini (2000)'s work on business cycles. A crucial feature of my analysis is that enforcement limitations have a greater impact on Pareto optima in which societal surplus is distributed unequally. This point also emerges in studies of efficient dynamic risk-sharing with limited enforcement (see Kocherlakota (1996)).

2. Environment

In this section, I describe the basic economic environment.

There is a unit measure of agents and there are two goods, labelled food and cars respectively. Food is divisible and cars are not.

All agents have identical preferences. They are expected-utility maximizers, with cardinal utility function over cars (c) and food (x) given by:

$$v \min(c, 1) + x$$

Here, v is a random parameter which is independent across all agents, with a continuous probability density function f and a cumulative distribution function F. The support of v is equal is an interval $[v_{\min}, v_{\max}]$ in the nonnegative extended reals (so $v_{\max}$ could be infinity).

All agents are initially endowed with X units of food, where $X > v_{\max}$. There are two types of technologies available to turn food into cars[2]. The first transforms γ_H units of food into 1 car; the second transforms γ_L units of food into 1 car, where $\gamma_H > \gamma_L$. I call the first technology *primitive* and the second technology *advanced.* A key feature of the environment is that there is a fixed cost Ψ (per-capita!) of adopting the advanced technology. I refer to this cost as being the cost of adoption.

To simplify the analysis, I assume that $\gamma_L > v_{\min}$; the results can easily be extended to environments in which this restriction is not satisfied.

There are three stages in the environment. In the first stage, the technology choice is made. In the second stage, agents learn their realization of v. The realization of v is private information to the affected agent. In the third stage, two agents receive their endowments of food, and production/consumption both take place.

I want to consider two versions of the above physical and informational setting. The first is a full-enforcement environment (labelled FE in what follows). Here, any agent can only leave the society with his X units of food before knowing the realization of his preference parameter. No departing agent can transform food into cars.

The second environment is a limited-enforcement environment (labelled LE). In this setting, an agent can costlessly leave the society with his X units of food after learning the realization of his preference parameter. Again, a departing agent cannot transform food into

[2] An equivalent formulation is to have agents endowed with time, which they can transform into food on their own, and have the two technologies convert time into cars.

cars.

3. Incentive-Feasible Allocations

In this section, I build some formal language to describe what is achievable in the two societies. I assume throughout that there are only two distinguishable groups, 1 and 2, of households, and a measure θ_i of the group i agents. Note that the two groups of households are identical in terms of preferences and enforcement constraints. Without loss of generality, assume $\theta_1 \leq \theta_2$.

Given this assumption, an *allocation* is a 5-tuple $(c_1, x_1, c_2, x_2, \delta)$ such that:

$$
\begin{aligned}
c_i &: [v_{\min}, v_{\max}] \to \{0,1\}, i \in \{1,2\} \\
x_i &: [v_{\min}, v_{\max}] \to [0,\infty), i \in \{1,2\} \\
\delta &\in \{0,1\}
\end{aligned}
$$

Here, c_i is the group i's consumption of cars (dependent on utility parameter v), x_i is the group i's consumption of food, and δ is the choice of technology ($\delta = 1$ is equivalent to choosing to adopt the advanced technology). An allocation is *feasible* if it satisfies:

$$
\begin{aligned}
X \geq\ & (\delta\gamma_L + (1-\delta)\gamma_H) \sum_{i=1}^{2} \int_{v_{\min}}^{v_{\max}} \theta_i c_i(v) f(v) dv \\
& + \sum_{i=1}^{2} \int_{v_{\min}}^{v_{\max}} \theta_i x_i(v) f(v) dv + \Psi\delta
\end{aligned}
$$

This condition guarantees that the per-capita amount of food exceeds the amount required to produce the allocated cars, the amount needed for the allocated food, and the amount needed to adopt the advanced technology.

In both environments, information and enforcement limitations affect what is achievable. It is straightforward to show that the Revelation Principle (Myerson (1979)) applies to this environment. In environment FE, an allocation is *incentive-compatible* if it satisfies:

$$vc_i(v) + x_i(v) \geq vc_i(v') + x_i(v') \text{ for all } v, v' \text{ in } [v_{\min}, v_{\max}]$$

$$\int_{v_{\min}}^{v_{\max}} [vc_i(v) + x_i(v)] f(v) dv \geq X$$

for $i = 1, 2$. The first condition requires truth-telling, and the second condition is an ex-ante participation constraint. In environment LE, an allocation is *incentive-compatible* if it satisfies:

$$\begin{aligned} vc_i(v) + x_i(v) &\geq vc_i(v') + x_i(v') \text{ for all } v, v' \text{ in } [v_{\min}, v_{\max}] \\ [vc_i(v) + x_i(v)] &\geq X \text{ for all } v \text{ in } [v_{\min}, v_{\max}]. \end{aligned}$$

The latter condition is an ex-post participation constraint.

In either environment, an allocation is *incentive-feasible* if it is simultaneously incentive-compatible and feasible. Finally, an incentive-feasible allocation is defined to be Pareto optimal if there is no other incentive-feasible allocation that provides as much utility to both groups of agents and more utility to one group.

The following lemma delivers a simple characterization of incentive-feasible allocations.

Lemma 1. In environment FE, an allocation (c, x, δ) is incentive-feasible if and only:

$$c_i(v) = 1 \text{ if } v_{\max} \geq v \geq p_i$$

$$c_i(v) = 0 \text{ if } v < p_i$$

$$x_i(v) = X + t_i - c_i(v)p_i$$

where:

$$p_i \in [v_{\min}, v_{\max}]$$

$$t_i \in [p_i - X, \infty)$$

$$\sum_{i=1}^{2} t_i\theta_i + \sum_{i=1}^{2} \theta_i(1 - F(p_i))(\gamma_L\delta + (1-\delta)\gamma_H - p_i) + \Psi\delta \leq 0$$

$$\int_{p_i}^{v_{\max}} (v - p_i)f(v)dv + t_i \geq 0 \text{ for } i = 1, 2$$

An allocation is incentive-feasible in environment LE if and only if it satisfies the above conditions and $t_i \geq 0$ for $i = 1, 2$.

Proof. It is straightforward to show that any allocation which satisfies these conditions is incentive-feasible. It is more difficult to prove the converse. Consider an arbitrary incentive-compatible allocation (c, x, δ). I first prove that there exists p_i in $[v_{\min}, v_{\max}]$ and t_i in $[p_i - X, \infty)$ that satisfy the first two conditions in the theorem. Let $C_{ij} = \{v|c_i(v) = j\}$.

Suppose first that $C_{i1} = [v_{\min}, v_{\max}]$ for some i. Truth-telling implies that $x_i(v) = x_i(v')$ for almost all v, v' in S. Then, define $p_i = v_{\min}$ and $t_i = x_i(v) - X + p_i$. These satisfy the conditions in the theorem. The proof is similar for $C_{i0} = S$.

Suppose instead that v is in C_{i1} and v' is in C_{i0}. Then, truth-telling implies that $x_i(v') = x_i'$ for all v' in C_{i0} and $x_i(v) = x_i$ for all v in C_{i1}. Define $t_i = x_i' - X$, and define $p_i = x_i' - x_i$. Suppose $v' > p_i$;then, a type v' should claim to be a type v. Suppose instead that $v < p_i$; then a type v should claim to be a type v'.

This proves that $c_i(v) = 1_{\{v_{\max} \geq v \geq p_i\}}$, and that $x_i(v) = X + t_i - p_i c_i(v)$. The other conditions follow from feasibility, and the ex-ante participation constraint.

In environment LE, $x_i(v) + vc_i(v) \geq X$, which is equivalent to $t_i - p_i c_i(v) + vc_i(v) \geq 0$ for almost all v in S, or $t_i \geq 0$. ■

According to this characterization, in an incentive-feasible allocation, there is a price p_i for cars for each group i. Agents choose whether or not to pay that price, depending on their realization of v. The proceeds of these sales are used to defray the costs of producing the cars, and distributed (via the transfers t_1 and t_2) among the various agents. In environment (LE), agents who have $v \leq p_i$ must receive a nonnegative amount of food, or they will walk away after learning their utility parameter. Henceforth, I describe incentive-feasible allocations in both environments by the associated 5-tuple $(p_1, p_2, t_1, t_2, \delta)$.

4. Main Results

In this section, I derive the main results. The results concern the adoption decision in two different Pareto optima in the limited enforcement economy and in arbitrary Pareto optima in the full enforcement economy.

The first Pareto optimum in economy LE that I consider is an egalitarian Pareto optimum in which all agents share social surplus evenly. It is an allocation (p, p, t, t, δ) which solves the problem EP:

$$\max_{p,h,\delta} \int_p^{v_{\max}} (v - p) f(v) dv + t$$

$$s.t. \ (\delta\gamma_L + (1-\delta)\gamma_H - p)(1 - F(p)) + t + \Psi\delta \leq 0$$

$$s.t. \ v_{\min} \leq p \leq v_{\max}, \ 0 \leq t < \infty, \delta \in \{0, 1\}$$

In this problem, the planner maximizes the typical agent's utility, subject to the resource constraint, and subject to the inequality restrictions on (p,t). Note that $t \geq 0$, reflecting the limited enforcement in the environment.

It is trivial to see that the resource constraint binds in this maximization problem. Once we substitute out for t in the objective, it is clear that EP is equivalent to the problem EP':

$$\max_{p,\delta} \int_p^{v_{\max}} (v-p)f(v)dv + (1-F(p))(p-\gamma_L\delta-\gamma_H(1-\delta)) - \Psi\delta$$

$$v_{\min} \leq p \leq v_{\max}$$

$$0 \leq (1-F(p))(p-\gamma_L\delta-\gamma_H(1-\delta)) - \Psi\delta$$

Here, the objective is the sum of two pieces which can be interpreted as consumer and producer surplus respectively (where we think of F as being a demand curve). In keeping with this interpretation, define:

$$PS(\delta) = \max_p (1-F(p))(p-\gamma_L\delta-\gamma_H(1-\delta)) - \Psi\delta$$

to be the producer surplus associated with adoption decision δ. This is the net amount of food generated by producing a car for each agent with $v \geq p$ in exchange for p units of food.

The following lemma shows that if adoption of the advanced technology increases producer surplus, then adoption also increases the sum of consumer and producer surplus.

LEMMA 2. Suppose $PS(\delta) > 0$ for all $\delta \in [0,1]$, and $PS(1) > PS(0)$. Then, $\delta = 1$ in an egalitarian Pareto optimum in environment LE.

Proof. For δ in $[0,1]$, define $TS_{LE}(\delta)$ to be:

$$\max_p \int_p^{v_{\max}} (v-p)f(v)dv + (1-F(p))(p-\gamma_L\delta-\gamma_H(1-\delta)) - \Psi\delta$$

$$0 \le (1-F(p))(p-\gamma_L\delta-\gamma_H(1-\delta)) - \Psi\delta$$

$$v_{\min} \le p \le v_{\max}$$

the total surplus for a given adoption decision δ. Here, I artificially allow δ to lie in the unit interval. Clearly, $\delta = 1$ in the egalitarian Pareto optimum if and only if $TS_{LE}(1) > TS_{LE}(0)$.

Note that the objective function in this definition is equivalent to:

$$\int_p^{v_{\max}} (v-\delta\gamma_L-(1-\delta)\gamma_H)dF(v) - \Psi\delta$$

and so is strictly decreasing in p. This immediately implies that the solution $p^*(\delta)$ to the maximization problem is the smallest value of p that satisfies the constraint with equality. Also, the monotonicity of the objective also implies that any p that lies in the constraint set is strictly larger than the solution $p^*(\delta)$.

Next, consider the maximization problem in the definition of producer surplus. Because producer surplus is positive, we know that if $p_{PS}(\delta)$ solves the producer surplus problem, $p_{PS}(\delta)$ is greater than $p^*(\delta)$.

By the envelope theorem:

$$TS'_{LE}(\delta) = [(1-F(p_{TS}(\delta))(\gamma_H-\gamma_L) - \Psi](1+\lambda(\delta))$$

where $\lambda(\delta)$ is the multiplier on the constraint. Similarly:

$$PS'(\delta) = (1-F(p_{PS}(\delta)))(\gamma_H-\gamma_L) - \Psi$$

But, $p_{PS}(\delta) > p_{TS}(\delta)$, and so $PS'(\delta) < TS'(\delta)$ for all δ. The lemma follows. ■

The intuition behind the proof is simple. The effect of technology adoption is to reduce the marginal cost of production for every unit produced. Maximizing total surplus necessarily involves giving cars to more people than maximizing producer surplus alone. Hence, the effect of technology adoption on total surplus is larger than for producer surplus.

In what follows, I maintain the following two assumptions:

*A*1. $\delta = 1$ in the egalitarian Pareto optimum

*A*2. $PS(1) - PS(0) < 0$

These assumptions say that technology adoption is worthwhile according to total surplus, but not worthwhile according to producer surplus. Note that Lemma 2 implies that the converse cannot be true.

I now turn to considering adoption in the full enforcement environment. The next result is that under assumption $(A1)$, the advanced technology is adopted in all Pareto optima in environment FE, regardless of the distribution of societal surplus.

PROPOSITION 1. *Under assumption* $(A1)$, *in the environment with full enforcement, the advanced technology is adopted in any Pareto optimal allocation.*

Proof. First, define total surplus to be:

$$\begin{aligned} TS(\delta) &= \max_p \{ \int_p^{v_{\max}} (v - p) f(v) dv \\ &\quad + (1 - F(p))(p - \gamma_L \delta - \gamma_H (1 - \delta)) - \Psi \delta \} \end{aligned}$$

In the solution to this problem, $p = \gamma_L \delta + (1 - \delta)\gamma_H$. This implies that $TS(0) = TS_{LE}(0)$, and $TS(1) > TS_{LE}(1)$. (See the Proof of Lemma 2 for the definition of TS_{LE}.) Hence, $TS(1) - TS(0) > 0$ (by assumption $A1$). Note that:

$$TS'(\delta) = (1 - F(\gamma_L \delta + (1-\delta)\gamma_H)))(\gamma_H - \gamma_L) - \Psi$$

Now, consider a Pareto optimal allocation $(p_1, p_2, t_1, t_2, \delta)$ that delivers utilities (u_1, u_2) to the two groups. Given δ, such an allocation must be the minimal cost way of providing these utilities; if it isn't, then we can change to a lower-cost way of providing these utilities, and hand out the extra resources to one of the two groups. Let $RC(\delta, u_1, u_2)$ be the minimal resource cost of delivering ex-ante utility u_i to group i:

$$\begin{aligned}
RC(\delta, u_1, u_2) \quad = \quad & \min_{p_i, t_i} \sum_{i=1}^{2} \theta_i [(\gamma_L \delta + \gamma_H (1-\delta) - p_i)(1 - F(p_i)) + t_i] - \Psi \delta \\
& s.t. \\
& \int_{p_i}^{v_{\max}} (v - p_i) f(v) dv + t_i = u_i, i = 1, 2 \\
& t_i + X \geq p_i, i = 1, 2
\end{aligned}$$

(As in the definitions of total and producer surplus, let $\delta \in [0, 1]$.)

I claim in a solution to this cost minimization problem, $p_i \leq \gamma_L \delta + (1-\delta)\gamma_H$ for $i = 1, 2$. The first order conditions to this problem are:

$$\theta_i (1 - F(p_i)) + f(p_i) \theta_i (\gamma_L \delta + (1-\delta)\gamma_H - p_i) = (1 - F(p_i)) \lambda_i + \eta_i$$

$$\lambda_i - \theta_i + \eta_i = 0$$

where λ_i is the multiplier on the utility constraint for group i agents, and η_i is the multiplier on the resource constraint for group i agents. Together, these imply that:

$$f(p_i)\theta_i(\gamma_L\delta + (1-\delta)\gamma_H - p_i) = \eta_i F(p_i) \geq 0$$

Hence, if $p_i^*(\delta, u_1, u_2)$ is part of the solution to the cost-minimization problem, $p_i^*(\delta, u_1, u_2) \leq \gamma_L\delta + \gamma_H(1-\delta)$.

Now, differentiate RC with respect to δ:

$$RC_\delta(\delta, u_1, u_2) = \sum_{i=1}^{2} \theta_i(\gamma_L - \gamma_H)(1 - F(p_i^*(\delta, u_1, u_2))) - \Psi$$

But because the solution $p_i^*(\delta, u_1, u_2)$ is no larger than $(\delta\gamma_L + (1-\delta)\gamma_H)$:

$$|RC_\delta(\delta, u_1, u_2)| \geq TS'(\delta)$$

for all δ. It follows that:

$$\begin{aligned} & RC(0, u_1, u_2) - RC(1, u_1, u_2) \\ > \; & TS(1) - TS(0) \\ > \; & 0 \end{aligned}$$

■

In environment FE, the fixed cost of adoption is paid by lump-sum transfers, instead of through the car price as in environment LE. This means that there is no necessity in environment FE to incur the "welfare triangle" social cost associated with having car prices above marginal cost. It follows that it is always Pareto optimal in environment FE to provide a car to at least as many agents as in the egalitarian Pareto optimum in environment LE. The gain to adoption is proportional to the fraction of agents who receive cars; hence, there are larger gains to adoption when minimizing resource costs than when maximizing total surplus.

Finally, I consider a second Pareto optimum in environment LE, the *maximal-inequality* Pareto optimum. In this Pareto optimum, all of the surplus is given to the smaller group of agents (namely, group 1 agents). It solves the following problem $P1$:

$$\begin{aligned}
&\max_{p_1,p_2,t_1,t_2,\delta} \int_{p_1}^{v_{\max}} (v-p_1)f(v)dv + t_1 \\
&s.t. \int_{p_2}^{v_{\max}} (v-p_2)f(v)dv + t_2 \geq 0 \\
&\sum_{i=1}^{2} \theta_i(1-F(p_i))[\delta\gamma_L + (1-\delta)\gamma_H - p_i] + \sum_{i=1}^{2} \theta_i t_i + \Psi\delta \leq 0 \\
&v_{\min} \leq p_i \leq v_{\max}, 0 \leq t_i < \infty, \delta \in \{0,1\}
\end{aligned}$$

In other words, we maximize group 1 agents' utility, subject to group 2 agents' utility being willing to go along with the contract rather than simply consuming their food, and subject to the resource constraint.

Note that in this problem, the ex-ante participation constraint is implied by the inequality restrictions on p_2 and t_2, and so we can drop it. As well, it is trivial that in any optimum, $t_2 = 0$. By substituting the resource constraint into the objective, and multiplying through by θ_1, we can rewrite the maximal-inequality Pareto problem as the following problem $P2$.

$$\begin{aligned}
&\max_{p_1,p_2,\delta} \theta_1 \int_{p_1}^{v_{\max}} (v-p_1)f(v)dv + (1-F(p_1))[p_1 - \delta\gamma_L - (1-\delta)\gamma_H] \\
&\qquad +\theta_2(1-F(p_2))[p_2 - \delta\gamma_L - (1-\delta)\gamma_H] - \Psi\delta \\
&s.t.\ v_{\min} \leq p_i \leq v_{\max}, \delta \in \{0,1\}
\end{aligned}$$

We can interpret the objective of $P2$ as being a weighted average of two pieces. The first is:

$$\int_{p_1}^{v_{\max}} (v - p_1) f(v) dv + (1 - F(p_1))[\delta\gamma_L + (1-\delta)\gamma_H - p_1] - \Psi\delta$$

and is the total surplus to the group 1 agents of producing cars at cost $[\delta\gamma_L + (1-\delta)\gamma_H]$ and selling them to group 1 agents at price p_1. The second piece is:

$$(1 - F(p_2))[\delta\gamma_L + (1-\delta)\gamma_H - p_2] - \Psi\delta$$

This is the producer surplus of selling cars to group 2 agents at price p_2.

If θ_1 is sufficiently small, then the second piece of the objective dominates, and, because of $A2$, it is no longer optimal for group 1 agents to set $\delta = 1$. Intuitively, the group 1 agents are both consumers of cars and monopolists in the sale of cars. If θ_2 is sufficiently large relative to θ_1, the monopolistic motive dominates their problem.

This kind of thinking leads to the following proposition.

Proposition 2. *Under Assumption* ($A2$), *in the environment with limited enforcement, if* θ_1 *is sufficiently near* 0, *then the primitive technology is used in any maximal-inequality Pareto optimum.*

Proof. Let $V(\delta)$ be the objective in $P2$ for a given δ, given that we maximize with respect to p_1 and p_2. Then:

$$\begin{aligned} & V(1) - V(0) \\ = \;& \theta_1 \max_{p_1}[\int_{p_1}^{v_{\max}} (v - p_1) f(v) dv + (1 - F(p_1))(p_1 - \gamma_L)] \\ & -\theta_1 \max_{p_1}[\int_{p_1}^{v_{\max}} (v - p_2) f(v) dv + (1 - F(p_1))(p_1 - \gamma_H)] \end{aligned}$$

$$+\theta_2 \max_{p_2}(1 - F(p_2))(p_2 - \gamma_L)$$

$$-\theta_2 \max_{p_2}(1 - F(p_2))(p_2 - \gamma_H)$$

$$-\Psi$$

Hence, for θ_1 sufficiently small:

$$V(1) - V(0) < 0$$

and $\delta = 0$ is optimal. ■

Thus, in a world with limited enforcement, a sufficiently unequal Pareto optimum will feature non-adoption. There are two key ingredients to this result. First, because of limited enforcement, it is not possible to share social surplus across all agents. Second, because of inequality, the objective of the planner is quite different from the goal of maximizing total societal surplus.

5. Non-Adoption of Arbitrarily Good Technologies

The above results would be uninteresting if they relied on the adoption cost Ψ's being very large while the gap between γ_H and γ_L is near zero. The situation in the world appears to be exactly the opposite: technologies have very different productivity levels and adoption costs appear to be small.

In this section, I address this concern. I show that Assumptions $A1$ and $A2$ can hold for arbitrarily large values of $(\gamma_H - \gamma_L)$, as long as demand is sufficiently inelastic. Consider the following sequence of economies, indexed by n:

$$F_n(\nu) = 1 - \nu^{-1-1/n}, \nu \geq 1$$

$$\begin{aligned}
\gamma_{Hn} &= (1-n^{-0.5})^{-n} \\
\gamma_{Ln} &= 0 \\
\Psi_n &= \Psi, 0 < \Psi < 1
\end{aligned}$$

We can think of F_n as being a demand curve with elasticity $(1+1/n)$. It is easy to show (using L'Hopital's Rule) that as n goes to infinity, γ_{Hn} converges to infinity, so that the primitive technology is getting arbitrarily worse than the advanced technology.

Now, define:

$$\begin{aligned}
\Delta_n^{prod} &= PS(1) - PS(0) + \Psi \\
&= \max_{p\geq 1} p(1-F_n(p)) - \max_{p\geq 1}(p-\gamma_{H_n})(1-F_n(p)) \\
\Delta_n^{tot} &= \int_1^{\infty} v f_n(v)dv - \int_{\gamma_{H_n}}^{\infty}(v-\gamma_{H_n})f_n(v)dv
\end{aligned}$$

I can show that for n arbitrarily large, $\Delta_n^{prod} < \Psi < \Delta_n^{tot}$. Hence, for n large, assumptions $A1$ and $A2$ are satisfied. There is a Pareto optimum in which the advanced technology is not adopted, even though γ_{Hn} is arbitrarily large.

To demonstrate this conclusion, note first that:

$$\begin{aligned}
\lim_{n\to\infty} \Delta_n^{tot} &= \lim_{n\to\infty}[\int_1^{\gamma_{H_n}} v f_n(v)dv + \gamma_{H_n}(1-F(\gamma_{H_n}))] \\
&= \lim_{n\to\infty}[n^{-0.5}(n+1) + (1-n^{-0.5})] \\
&= \lim_{n\to\infty}(1+n^{0.5})
\end{aligned}$$

and so $\lim_{n\to\infty} \Delta_n^{tot} = \infty$. Also, note that:

$$\begin{aligned}
\Delta_n^{prod} &= \max_{p\geq 1} p(p^{-1/n-1}) - \max_{p\geq 1}(p-(1-n^{-0.5})^{-n})p^{-1/n-1} \\
&= 1-\max_{p\geq 1}(p-(1-n^{-0.5})^{-n})p^{-1/n-1}
\end{aligned}$$

By using the first order conditions, the optimal p for a monopolist using the primitive technology is given by:

$$(n+1)(1-n^{-0.5})^{-n} = \arg\max_{p\geq 1}(p-(1-n^{-0.5})^{-n})p^{-1/n-1}$$

Hence, as n grows large, the optimal mark-up for a monopolist gets bigger (because demand is getting less elastic). It follows that:

$$\begin{aligned}
\Delta_n^{prod} &= 1-n(1-n^{-0.5})^{-n}(n+1)^{-(n+1)/n}(1-n^{-0.5})^{n+1} \\
&= 1-n(n+1)^{-1}(1-n^{-0.5})(n+1)^{-1/n}
\end{aligned}$$

Again using L'Hopital's Rule:

$$\lim_{n\to\infty} \Delta_n^{prod} = 0$$

Along this sequence of economies, γ_{Hn} converges to infinity. However, because demand is getting less elastic, Δ_n^{prod} eventually falls below Ψ, although Δ_n^{tot} stays above Ψ. Thus, there are economies with arbitrarily large differences in costs between the two technologies, in which the primitive technology is used in some Pareto optimal allocations.

6. Monopoly and Foreign Competition

In this section, I consider two different trading arrangements within the context of environment LE. In both arrangements, there is a single firm which owns the two production technologies. The firm commits publicly to an adoption and pricing decision before agents know the realization of their preference parameters.

A key difference between my formulation of monopoly and the usual formulation is that the firm makes its adoption/pricing choices so as to maximize shareholder utility, not shareholder value. Because all agents have the same preferences, their decision is unanimous. I assume that the firm is able to charge different prices to shareholders and non-shareholders.

I next consider the impact of foreign competition on the economy. In particular, given that a particular monopolistic arrangement is in place, I ask whether opening the economy to outside cheap provision of cars makes all agents better off.

A. Monopoly in the Closed Economy

Given assumptions ($A1$) and ($A2$), I consider two monopolistic arrangements which differ in the specification of who owns the firm. In the first arrangement, the firm is evenly divided among all members of society. Hence, the firm's choice problem can be written as:

$$\max_{p,\delta} \int_{p}^{v_{\max}} (v-p)f(v)dv + (1-F(p))(p-\delta\gamma_L-(1-\delta)\gamma_H) - \delta\Psi$$

But this is simply the egalitarian Pareto optimum problem, with the resource constraint substituted into the objective. Under assumption ($A1$), in the solution to this problem, $\delta = 1$. This monopolist chooses to adopt the advanced technology.

In the second arrangement, a measure θ_1 of the agents own the firm. The other $(1-\theta_1)$ agents do not. Hence, the firm owners solve:

$$\max_{p_1,p_2,\delta} \theta_1 \int_{p_1}^{v_{\max}} (v-p_1)f(v)dv + \theta_1(1-F(p_1))(p_1-\delta\gamma_H-(1-\delta)\gamma_L) +$$
$$+(1-\theta_1)(1-F(p_2))(p_2-\delta\gamma_L-(1-\delta)\gamma_H) - \delta\Psi$$

But this maximization problem is the same as the maximal-inequality Pareto problem. Again, the monopolistic outcome is Pareto optimal. However, if θ_1 is sufficiently small, so that firm ownership is concentrated in a few hands, then the firm will choose not to adopt.

Thus, monopolistic outcomes are always Pareto optimal in this setting. There is a welfare triangle in the latter arrangement (because p_2 is higher than marginal cost). However, the enforcement limits mean that this triangle cannot be distributed to shareholders, and so it is not possible to create a Pareto superior outcome.

B. Foreign Competition: Pareto Improving?

I again consider the latter monopolistic arrangement, in which the monopoly is closely held. Suppose there is a world market for cars, in which agents can trade γ_L units of food for a car. Hence, in this world market, technology adoption has already taken place. Assuming that opening up to the world market is costless, can the society effect a Pareto improvement by doing so?

The answer to this question depends exactly on how opening up to world markets works. Suppose first that only the monopolistic firm is allowed to trade with the world market. Then, trade with the world market is Pareto-improving. In essence, the monopolistic firm is able to switch to the advanced technology without paying the adoption cost Ψ. The firm can charge the same prices, and make more profits; the shareholders are strictly better off and the non-shareholders are no worse off.

But suppose instead that any agent can trade with the world market. All of the non-shareholders are better off, because they can buy cars at the cheaper price of γ_L. However, because enforcement is limited, there is no way to transfer any of these benefits to the shareholders.

The shareholders face two effects. As consumers, they are better off because the price for cars is now γ_L instead of γ_H. As producers, though, they are worse off because they lose monopoly profits from the non-shareholders. As long as the firm is held by a sufficiently small fraction of the population, the latter effect dominates, and the shareholders are made worse off by opening up to foreign trade.

Thus, there will be no resistance to allowing the monopolistic firm to trade with the world market, as long as no other agent can. Under this scheme, the domestic firm switches from being a domestic producer of cars to a monopolistic middleman for foreign cars. In contrast, shareholders of a closely held monopoly will resist the alternative scheme of allowing all agents to trade with the world market.

7. Conclusion

In this paper, I consider an economic environment with a key friction: the inability to collect taxes from non-buyers of manufactured goods. I show that in societies of this type, adoption of an advanced manufacturing technology may not occur in Pareto optimal allocations in which societal surplus is concentrated in relatively few hands. Thus, social costs associated with income tax collection, combined with a sufficiently high degree of inequality, can generate especially strong barriers to adoption of superior technologies.

The basic intuition behind these results is simple. Consider a country in which a small ruling elite receives the profits from producing and selling manufactured goods. Will this elite pay a small fixed cost to adopt a superior production technology? The answer depends on the elite's ability to tax. If the elite cannot impose taxes, then it finds adoption optimal only if increases in producer surplus are larger than the cost of adoption. However, if taxes are possible, then the elite can extract consumer surplus; it will make the adoption decision by comparing the cost of adoption to the gain in total surplus. The gain in total surplus may be much larger than the gain in producer surplus, especially if demand elasticity is low.

I believe that the results can be extended in several directions. First, imposing a weaker form of limited enforcement, in which agents can walk away with only a positive fraction of their food endowments, should not affect the results. However, in this setting, monopolistic outcomes may not be Pareto optimal unless the monopolistic firm is subsidized or can use a two-part pricing scheme. Second, I conjecture that the results are valid if agents can consume arbitrary amounts of cars (instead of 0 and 1). The structure of incentive-feasible allocations becomes more complex, because they are based on sophisticated price/quantity schedules. However, as long as it is not possible to fully extract consumer surplus from car consumers using such schedules, the results will still be valid.

In this paper, I have emphasized the impact on technology adoption of difficulties in income taxation. Of course, in reality, there is an opposite feedback from the level of development of a society to its ability to collect taxes. Understanding the interaction between these two forces is an interesting topic for future research.

The analysis has at least two robust empirical implications. First, the model predicts that low-TFP countries should have high inequality, and should have limited taxation powers. Second, the discussion in Section 5 indicates that barriers to adoption should be especially pronounced for goods with low demand elasticities. These facts are qualitatively consistent with the existence of barriers in textiles in India documented by Parente and Prescott (1999) and Clark (1987). However, it would be interesting to investigate these predictions quantitatively in a more elaborate version of the basic structure set forth in this paper.

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