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Guns, Latrines, and Land Reform: Dynamic Pigouvian Taxation†

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Standard theory suggests that governments may wish to impose Pigouvian subsidies or taxes on goods which create externalities, such as latrines or cars. We argue that dynamically optimal Pigouvian policies for durable goods will differ from statically optimal policies, since expectations over future government subsidies, taxes, and regulatory policy on durables affect consumers' current purchase decisions.

Consider, for example, a government of a growing developing country with widespread open defecation choosing subsidies for latrines to reduce disease transmission. Statically optimal Pigouvian subsidies will grow over time as the economy develops, but if the government raises subsidies over time, consumers will have incentives to delay purchases, reducing the benefit of the subsidy. In the extreme, delays in private investment caused by anticipated subsidy growth may dissipate up to 100 percent of the private benefits of the transfers to the consumer, and if the durable generates positive externalities, these delays could potentially lower welfare in the economy relative to a counterfactual without subsidies.

We consider the dynamic game when not only do consumer decisions depend on anticipated future government policy, but optimal government policy is influenced by consumers' purchase decisions for durables. We show that if the government does not have the ability to commit, there will be multiple Pareto-rankable Markov perfect Nash equilibria. If the government can commit to a future subsidy path, it can eliminate inferior equilibria. Ideally it would commit to first instituting and then withdrawing subsidies, so as to incentivize consumers to adopt the durable good at the socially, rather than privately, optimal date. A government that can commit to a constant subsidy, but not a temporary subsidy, will need to spend more to induce consumers to adopt at the socially optimal date. The problem could potentially be addressed by subsidies on the flow value of durable services or fines for not possessing the durable, but these policies may be difficult to implement.

Government commitment to subsidy paths may be difficult in the presence of multiple subsidy providers, such as NGOs. As outlined above, anticipation of foreign subsidies could reduce welfare by delaying private investment. This provides a potential justification for governments wishing to regulate NGO subsidies for durables, as well a new potential rationale for the view of many aid skeptics that aid is not only partially dissipated in waste, but could potentially harm the recipient population (although we are not arguing that there is empirical evidence for this theoretical possibility). The problem could be addressed if NGOs subsidize nondurables rather than durables.

The model can be extended to the case in which durables create negative externalities, and to introduce political-economy considerations. For example, from a static perspective, a political party that believes guns create negative externalities would want to introduce Pigouvian taxes or regulations. However, consumers may stockpile guns between the time the party begins campaigning for such a policy and its eventual implementation. In extreme cases, this dynamic force may make the gun control policy counterproductive, leading the government to abandon it altogether. To take another example, a political party that announces an intent to redistribute land as part of a land reform may reduce current owners' incentive to invest in the land, thus reducing the benefits of maintaining existing

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property rights and making land reform more attractive to other political parties and to the median voter.

I. Setting

A. *Agents and Structure of the Game*

We consider a game with two types of agents, the individuals who purchase the durable, e.g., a latrine, and the organizations which provide the subsidies or taxes, typically the government. We consider two types of games: one in which the government is able to commit at time 0 to the future path of subsidies or taxes and one in which they are not. When the government is able to commit, at time 0 they decide their path of subsidies $s(t)$ and then the individual decides each period whether to buy the durable. The game is solved by first solving the individuals' decisions of whether and when to buy the durable, given the subsidy path, and then solving the government's decision on the optimal subsidy level, given the individuals' reaction functions. In reality government might be restricted to a class of functions for $s(t)$, so we also consider two special cases: when governments can only commit to a constant subsidy path, and when they can commit to a path of statically optimal Pigouvian subsidies. When the government is not able to commit, the timing of the game is that in each period the government sets a subsidy $s(t)$ and then individuals decide whether to buy the durable at price $p(t)$. We only consider Markov perfect Nash equilibria (MPNE) in pure strategies. Full derivations of the results below can be found in the working paper version (Kremer and Willis 2016).

B. *Technology, Preferences, and the Equilibrium Path of Nondurable Consumption*

We consider a closed-economy continuous time Ramsey model with exogenous technological progress at rate $g > 0$, discount rate ρ, and homogeneous agents. We assume a standard Cobb-Douglas production function in capital and labor with exogenous rate of technology change g. Utility is quasilinear in services from the durable u_t^I and total spillovers from others' durables, u_t^S, which are proportional to the number of other people using the durable. Consumption in the other goods has constant intertemporal elasticity of substitution θ, so that discounted lifetime utility is

$$\int_0^\infty e^{-\rho t}\left(c_t^{1-\theta}/(1-\theta) + u_t^I + u_t^S\right)dt.$$

All prices in the paper are in units of consumption of other goods. We assume that the value of the services the durable provides, in that unit, grows with consumption growth, which we think is the relevant case for latrines and many other examples of durables which the government might subsidize. Since we assume perfect credit markets with interest rate r_t, the Euler equation tells us $\frac{\dot{u}'(c_t)}{u'(c_t)} = \rho - r_t$. Being in the steady state of the Ramsey model, we have that r_t is constant and $r - \rho = \theta g$. Thus,

$$u'(c_t) = u'(c_0)e^{-\theta g t}. \tag{1}$$

The initial consumption level will be tied down by the transversality condition so that the NPV of total consumption (durable and not durable) equals the NPV of wealth minus the NPV of net transfers to the government (taxes).

We assume that the government has lexicographic preferences over social welfare and the cost of subsidies, with social welfare being dominant. This is a simplification and an approximation to the case where government can raise funds at low cost. We initially assume that the government can only subsidize or tax the purchase of the durable, for instance because other types of taxes or subsidies may be too costly to implement. In a later section we consider the case when the government has access to a wider variety of tools.

C. *Durable Good*

We assume that the durable, once installed, provides constant flow utility u_L and doesn't depreciate. Thus the present discounted utility of the durable is $\int_0^\infty e^{-\rho t}u_L\,dt = \frac{u_L}{\rho}$. Durables also provide a total social externality u_S, so that $u_t^S = \gamma(t)u_S$, where $\gamma(t)$ is the proportion of the population who have the durable at time t. We treat the utility from nondurables, own durables, and others' durables as separable, abstracting from potential complementarity or substitutability. The durable is always available on the private market, assumed perfectly competitive.

It has constant price p, assumed small relative to lifetime wealth and to the capital stock at purchase time, and assuming implicitly that the production technology grows at the same rate, g, as technology in the rest of the economy. Due to growing consumption, eventually everyone will buy the durable. We assume that the government offers a potentially time-varying subsidy $s(t)$ to this price, positive or negative, where $s(t) = 0$ if the government is not offering subsidies at time t. Define $p(t) = p - s(t)$ as the price at which the agent can buy the durable at time t.

II. Consumer's Problem

In the game with commitment, the individual knows the price path $p(t)$ from the start. In the general game without commitment, the individual only has beliefs over the future prices. However in equilibrium, as we consider pure strategy MPNE, these beliefs are correct, and hence we can also treat the consumer's problem as if they know the price path from the start in this case.

Given price path $p(t)$, individual demand satisfies

$$t^*(p(t)_{t\geq 0}) = \arg\max_t \frac{e^{-\rho t}}{u'(c_0)} \frac{u_L}{\rho} - e^{-rt}(p - s(t)).$$

Consider first the unsubsidized case, where the price is constant at p. In this case, the first order condition gives

$$u'(c_{t^*(p)}) = \frac{u_L}{pr}. \tag{2}$$

Implying the individually optimal purchase time, denoted t^*:

$$t^* := \frac{1}{\theta g}\ln\left(\frac{u'(c_0)pr}{u_L}\right). \tag{3}$$

Suppose the durable is offered at a one-time different price at time t. The willingness to pay for the durable in this case rather than at price p at time t^*, denoted $w_c(t)$, then equals

$$w_c(t) := \max\left\{\frac{pr}{\rho}e^{\theta g(t-t^*)} - \frac{p\theta g}{\rho}e^{r(t-t^*)}, 0\right\}. \tag{4}$$

Now consider the case of a general subsidy. If $s(t)$ is continuously differentiable, this gives the following first order condition:

$$e^{-\theta g t^*(p(t))}\Big(r\big(p - s\big(t^*(p(t))\big)\big) + s'\big(t^*(p(t))\big)\Big) = \frac{u_L}{u'(c_0)}.$$

Thus $s(t)$ has two effects: $t^*(p(t))$ decreases with its level, but increases with its slope.

III. Government's Problem

In this section we assume that the externality is positive. Everything follows, with inequalities reversed, for negative externalities. The socially optimal time for purchase of the durable, t_s^*, is that of the case of no externalities but with utility flow $u_L + u_S$, given by

$$t_S^* = \frac{1}{\theta g}\ln\left(\frac{u'(c_0)pr}{u_L + u_S}\right). \tag{5}$$

A. *Government Can Commit*

We consider how the government can offer the subsidies to get people to purchase the good at this time t_S^*, under various abilities to commit. If the government has full control over the subsidy path, the cheapest way for them to achieve the first best time is to offer a subsidy at the socially optimal time t_S^* which makes the individual indifferent between taking the subsidized price at t_S^* and the private price p at t^*, and to remove the subsidy immediately afterward. Such a subsidy satisfies $p - s^* = w_c(t_s^*)$, giving

$$s^* = p\left(\frac{u_S}{u_L+u_S} - \frac{\theta g}{\rho}\frac{u_L}{u_L+u_S}\left(1 - \left(\frac{u_L}{u_L+u_S}\right)^{\rho/\theta g}\right)\right). \tag{6}$$

If the government isn't able to commit to a whole price schedule, but only to a constant subsidy, then this subsidy s_c^* is greater than the subsidy with full commitment s^*:

$$s_c^* = \frac{u_S}{u_L + u_S}p > s^*. \tag{7}$$

B. *Government Cannot Commit*

If the government isn't able to commit upfront, they face a classic commitment problem: individuals know that if they don't buy at time t_S^* then the government will wish to raise its subsidy in the next period, since the monetary value of the externality will have increased. In our model this results in multiple equilibria.

PROPOSITION 1: *The MPNE in this case are all subsidy paths $s(t)$ such that: $s'(t) \leq \frac{u_L}{u'(c_t)} - r(p - s(t))\ \forall t \geq t_S^*$; $p - s(t) \leq w_c(t)\ \forall t \in [t_S^*, t^*)$; individuals prefer waiting for $p - s(t_S^*)$ rather than buying at $p - s(t)\ \forall t < t_S^*$. Such paths have subsidies which are bounded below at t_S^* by the outside option, and first best timing is achieved, but subsidies are not bounded above at t_S^*.*

PROOF:
See the online mathematical Appendix.

C. *Static Pigouvian Subsidies*

Suppose instead the government follows static Pigouvian subsidies $s^p(t)$, whose value rises over time: $s^p(t) = \frac{u_S}{\rho u'(c_t)}$. The individual demand equation then gives

$$t^*((p - s(t))_{t \geq 0}) = t_s^*.$$

This again gives the optimal time, but results in significantly larger subsidy payments than if the government could commit to a fixed subsidy level:

$$s_p^*(t_s^*) = \frac{r}{\rho} s_c^* > s_c^*. \tag{8}$$

D. *NGOs and Durables*

The previous section assumed an unchanging utility function for the government and a single provider of subsidies. Without commitment the game resulted in the first best timing, although at a higher cost. Now consider a case where either government preferences over subsidies or their ability to provide them over time may change, for example with the election of a new party, or a new provider of subsidies may arrive at a later date. Then agents may expect the subsidy to rise considerably in the future, causing them to delay purchase of the durable beyond the optimal time t_s^*, with associated loss of welfare.

NGOs often have preferences for subsidizing certain types of goods which may differ from those of the government. For example, some NGOs may consider latrines as merit goods and wish to subsidize them heavily. NGOs' preferences may also change over time, as may their presence in a region. When NGO preferences over subsidies are misaligned with those of the government, their subsidizing durables may undermine the ability of the government to commit to a subsidy path.

For a simple model of the potential adverse effects of subsidies on durables, suppose that the NGO will arrive at time t_N and then offer constant subsidy s_N. Suppose also that the individually optimal time to buy at the subsidized price $t^*(p - s_N) < t_N$, so that if the individual waits for the subsidy then they will purchase the durable as soon as the subsidy starts. As $p - s_N \to w_c(t_N)$, the willingness to pay for the durable at time t_N, either through s_N decreasing or t_N increasing, all of the individual benefit from the subsidy is dissipated. Further, if $t_N > t^*$, the optimal time to buy the unsubsidized durable, we see that the subsidy actually delays investment in the durable, because of expectations of future rises in the subsidy, and hence worsens externalities and thus overall national welfare, even if the subsidy is financed from abroad.

The problem could be solved by NGOs financing nondurables, but NGOs often prefer subsidizing durables to nondurables, believing the former to be more "sustainable."

E. *Tools Available to Government*

In the above we assumed that governments could only subsidize or tax goods through the purchase price. This is a reasonable assumption in many cases, for example such subsidies or taxes can often be added at the factory gate or point of sale, rather than going house to house which could be prohibitively expensive. In practice, alternative tools for funding may be available and may be more attractive (Ashraf, Glaeser, and Ponzetto 2016). One alternative approach would be to tax or subsidize *not* owning the good. Often such dual policies are equivalent. However, when the government is able to commit to either a future subsidy or fine in the future, if the policy is

correctly designed one will require money to pass through governments hands whereas the other will not, particularly appealing in places of high corruption. Namely, the subsidy offered once at the first best time will result in take-up then. The fine, imposed once just after the first best time, will result in take-up just before, with no fines needing to be collected. In practice such fines might be costly to run, and hence not credible.

The government might also have access to a flow subsidy or tax on ownership. While this is equivalent to a stock subsidy or tax at purchase when the stock value is the net present value of future flow values, there are different implications for the ability to commit. Offering the cash value of the social utility flow at all periods results in first best timing and may be simple to commit to. However, in many examples these flows will be small relative to collection costs, in which case such policies are unlikely to be used.

Another policy which may help with commitment, in the case of varying subsidies, is for the government to agree to pay the subsidies retroactively. However, such policies must be credible, since ex-post the government would want to renege on the retroactive payment.

F. *Decentralized Government Spending*

While we have so far focused on the effect of expectations on private behavior, the same mechanism can impact the public investment decisions. Namely, if local public infrastructure investments can be made at any time by local government, but may be subsidized in the future by national governments, then local government may forgo investment at the optimal time in order to wait for investment from the national government. As above, these delays can dissipate all the local surplus from the national government spending, and in the case of negative externalities, e.g., with poorly maintained highways, the national funding may actually reduce welfare. Again this suggests a role for early commitment by the national government to the future subsidies they will provide and under what conditions.

IV. Extensions to Other Settings

A. *Guns*

We now consider a case in which there is a durable with a negative externality which the government would like to tax, but there is a delay between the announcement of the intention to implement the policy and its actual implementation. Such delays are likely in practice, since changes to law take time, and political parties layout their policies in manifestos before coming to power.

The announcement of the policy will increase sales in the short term, contrary to the aims of the government and worsening the social externality. If the time gap is sufficiently long, then as in the example given above in the section on NGOs, introducing the policy may actually reduce welfare. If the government is to introduce tax T at time t, announcing this at time 0, the policy would reduce social welfare if the optimal time to buy a gun is later than T, $t^* > T$, and the gain from buying a gun just before the tax is introduced is greater than that from buying a gun at the optimal time once the tax is introduced

The Obama administration may be facing this problem. Gun sales spiked to their highest level in two decades after the Sandy Hook shootings. The *Washington Post*, following a similar spike after the San Bernardino shootings, wrote "This matches a pattern we've seen plenty of times in the past: tragedy, followed by calls for gun control, followed by surging firearm sales." (Ingraham 2016). If a per-period tax on ownership of guns is available, as seems potentially realistic in this case, then the problem goes away. Similarly, the problem also goes away if the government is able to announce a tax which will be applied retroactively from the announcement date.

B. *Land Reform*

Until now we have considered cases where expectations over future changes in optimal government policy act against the government's wishes. However, it is possible that the announcement of a future policy change could be self-fulfilling, by making the status quo less attractive. Take the example of land reform and consider a basic model of electoral competition. The main economic justification for private land holdings is that they encourage optimal investment in the land. However, these investments are conditional on beliefs of future ownership. Suppose a pro land reform party announces that, if elected, they will enact extensive land reform. If they have a chance of being elected, this

reduces the expected returns to investments in land by land owners, and hence in turn reduces such investments. However, these investments were the justification for not having land reform, and so the marginal voter shifts toward being positive toward land reform and hence so too does the other party, if it is marginal. This makes both land reform and potentially the election of the pro land reform party more likely.

V. Conclusion

Expectations over the government's future subsidies, taxes, and regulatory policy on durables, such as latrines or guns, affect consumers' current purchase decisions. In turn, consumers' purchase decisions affect optimal policy for future governments. We study the resulting dynamic game in a growing economy, arguing that dynamically optimal Pigouvian subsidies and taxes on durables will in general differ from their statically optimal levels. Governments seeking to encourage purchase of a particular durable may wish to commit to eventually reducing subsidies so as to advance consumers' optimal purchase time. In their original paper on the benefit of governments committing to rules, Kydland and Prescott (1977) give a somewhat related example in which, without a rule prohibiting it, individuals build on floodplains in the anticipation that ex-post the government will build costly flood defenses.

In a related paper, Kremer and Willis (2016), we consider the case in which infrastructure services can be provided through multiple technologies with different economies of scale. For example, in developing country settings, electricity can be supplied either publicly through the grid or privately through off-grid solar, water can be supplied through municipal systems or wells, and waste can be disposed of through a sewage system or through latrines. We consider a context in which consumers have heterogeneous wealth which lead to differences in individual optimal times to invest in durables. In the absence of commitment, there may be multiple equilibria, including equilibria in which the rich expect that the government will not provide infrastructure, and therefore invest early in private durables, in turn reducing incentives for the government to invest in infrastructure. To eliminate such potentially welfare-reducing equilibria, the government may wish to commit to install public infrastructure at a specified future time, and if it lacks the ability to do so, it may wish to tax private durables or build public infrastructure early. We show that greater inequality and slower growth both reduce the desirability of public infrastructure, and identify the circumstances in which segregation by wealth is more or less likely to emerge. Optimal policy also depends on the financing options available to the government: imperfect price discrimination may result in a hold-up problem and the use of other second best policies to raise revenue for the investment.

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